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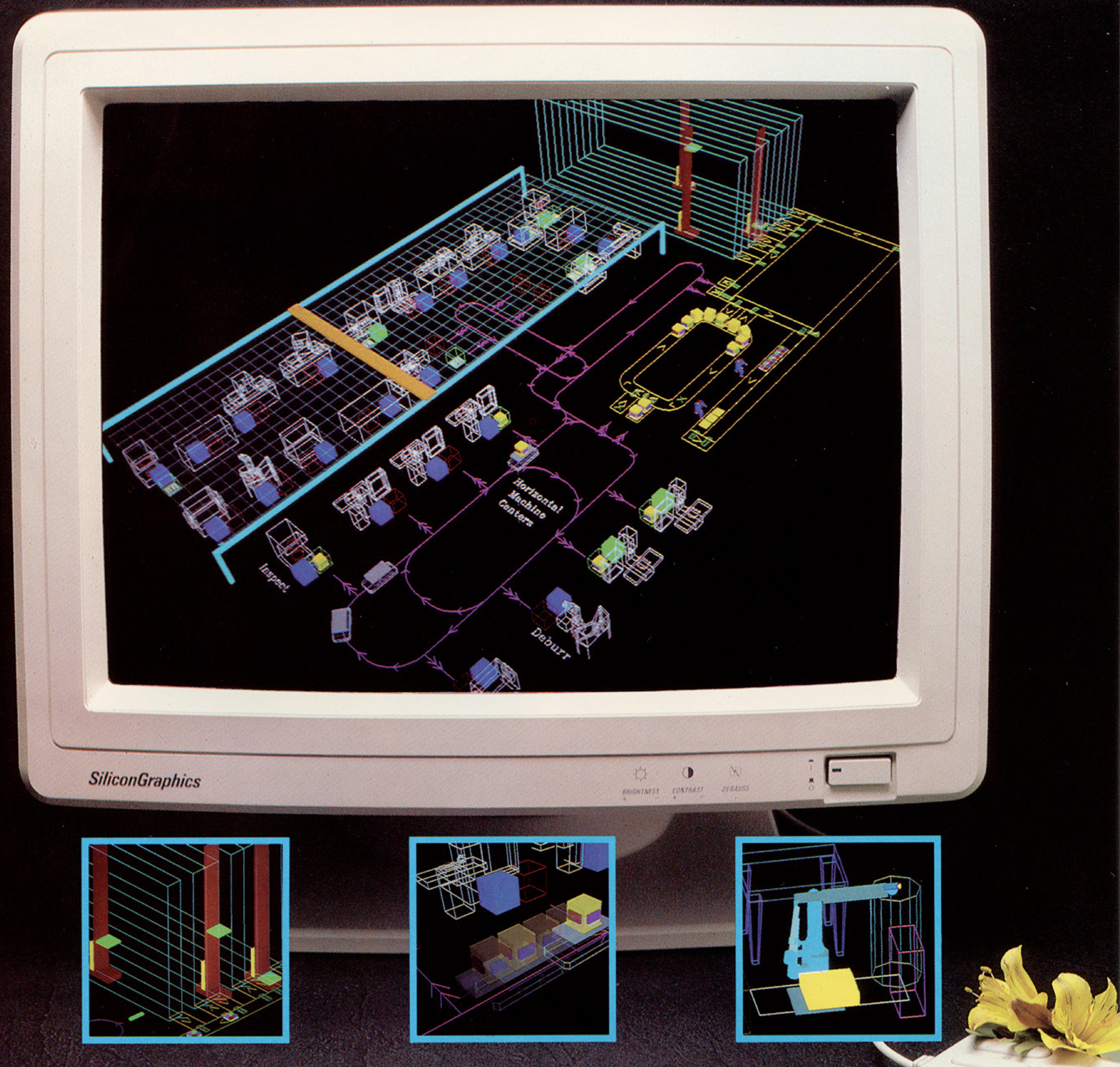

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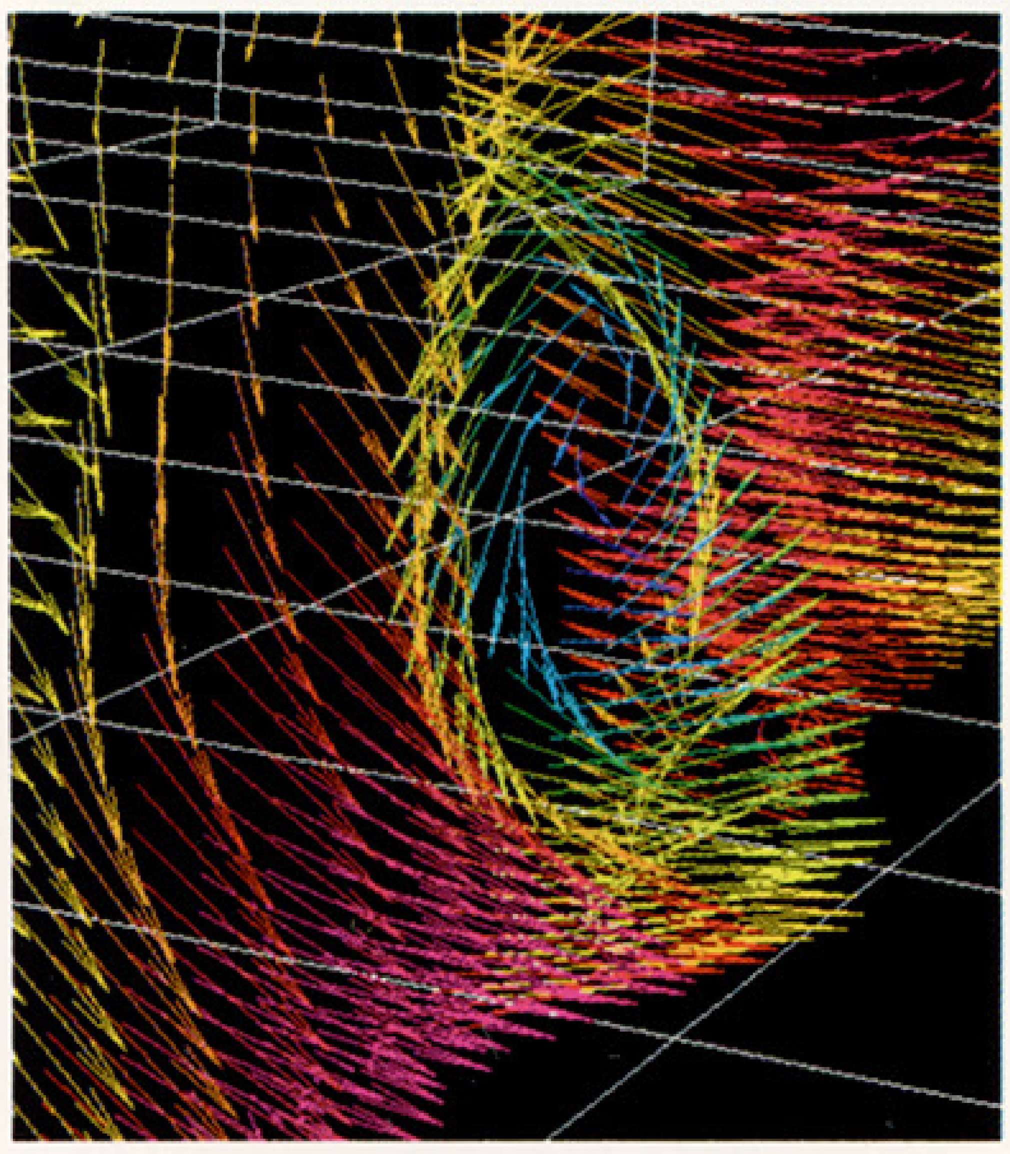

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FEATURES

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On The Cover

Waldo C. Graphic, an electronic muppet created by Pacific Data Images for Jim Henson Productions using an IRIS 4D/70GT.

About This Issue

Old Perspectives in a New World

Among hackers, the time-honored retort to heathen users with the temerity to ask about system or software usage is: "RTFM!" (Read the Manual!). But cherished as that attitude might be in programmer circles, it certainly doesn't play outside of the computing community.

Given that users in industry typically show more interest in exploiting computers than in understanding them, it follows that they should set great store by "ease-of-use." For many, in fact, the ideal solution would be a machine every bit as simple and accessible as the average telephone — an "information appliance," if you will.

Like any other appliance, you'd expect such a system to be reliable, inexpensive, inconspicuous, and simple to operate. Certainly, you wouldn't want to deal with a machine any more obtuse than a video recorder.

A pipe dream? Perhaps. But, as the following articles indicate, new electro-stereoscopy products are already available that make visual computing even easier and more natural than it has been to date. This is to say that, despite the physical limitations of 2D planar displays, a person using an enhanced IRIS 4D workstation can now study solid objects in *true* 3D. To benefit from the advance, one need only have normal vision. The interface is the same as that learned at birth: just open your eyes and look. Thus, while a manual might be required to explain *how* stereo vision works, no training will be necessary to take immediate advantage of what the technology has to offer.

As a sample of the difference stereo viewing can make, we've included a plastic stereoscope and more than 15 stereo image pairs in this issue. The stereoscope itself, of course, is a toy, but Silicon Graphics' new *StereoView* product is most certainly a tool for serious business. Improved designs and diminished ambiguity in the CAD/CAM, molecular modeling, medical imaging, and graphic arts arenas are just some of the expected benefits.

What's in it for you? That depends on *your* vision.

Mark Compton

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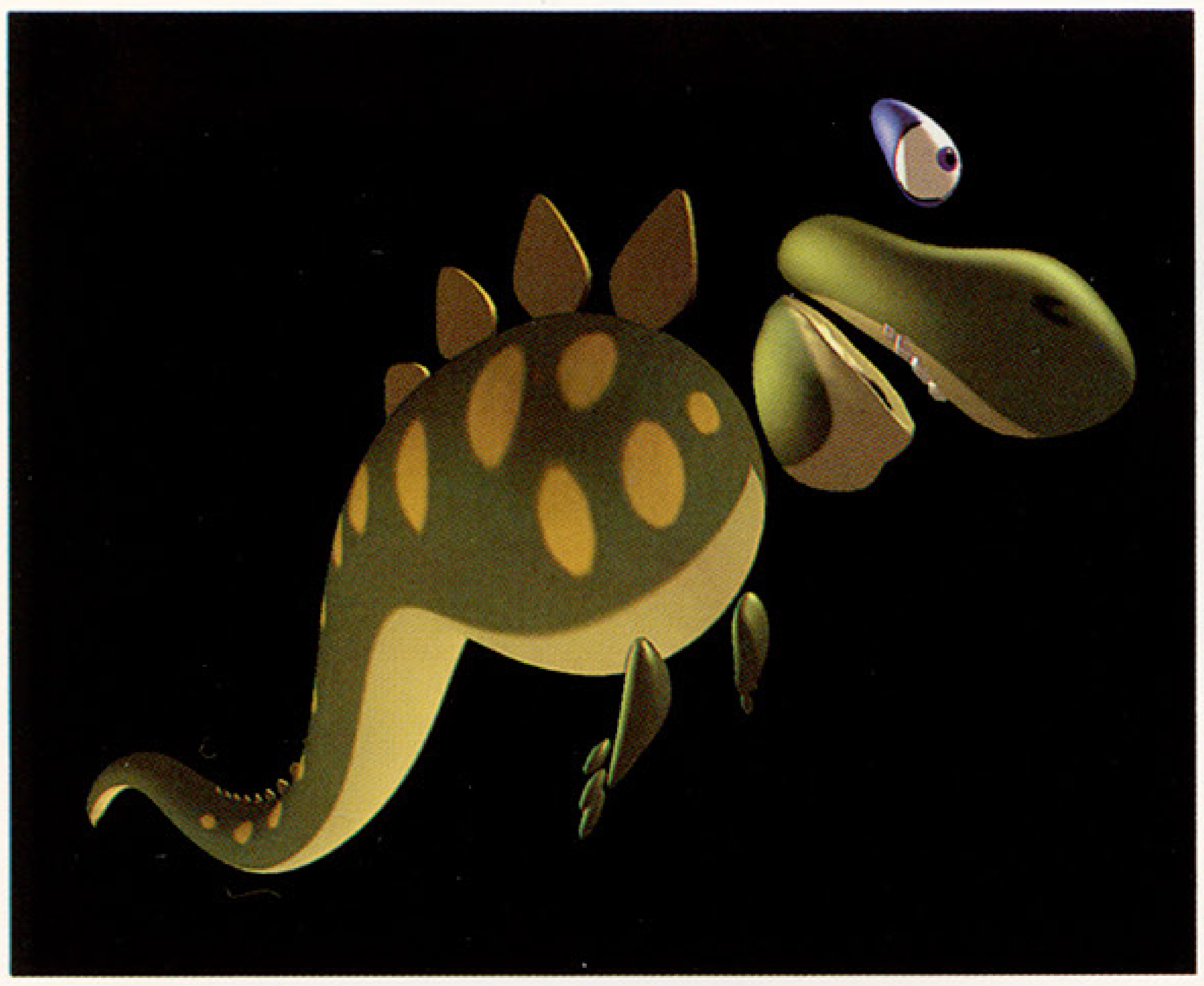
feature

THE DYNAMICS OF WALDO

The stuff that Waldo C. Graphic, the world's first real-time, computer-generated Muppet, is made of.



BY GAYE GRAVES

By the time of Waldo C. Graphic's television debut this spring on the *Jim Henson Hour* television series, he'd already left quite an impression. Brought to life on an IRIS 4D/70GT by Pacific Data Images (PDI) and Jim Henson Productions, Waldo had participated in every rehearsal, every improvisation, and every repeat take right along with Henson's cast of "live" Muppets.

In so doing, Waldo had realized a long-standing dream of Muppet master Henson. For at least five years, Henson had actively explored a number of options for employing a computer graphic buddy for Kermit and the gang. "We've long wanted to have a computer-generated character that people could react to much as they react to any other character," he explains. "Waldo, with all his capabilities, lets us do just that."

Among the computing alternatives explored before the Waldo project was the potential of using a Cray based at the now-defunct Digital Productions. PDI's producer on the Waldo project, Nancy St. John, had been working at Digital Productions when Henson first approached the group. As she recalls, "I just didn't believe that particular technology was right for the project. It's hard to bring a Cray into a studio setting. Still, at the time, no small machine was fast enough. Plus, nobody by then had been able to deal with the video output problem of compositing graphics with live action in real time."

Enter PDI. When Henson first approached the Sunnyvale, CA-based company in July 1988, he knew he was dealing with a group recognized for its high-end, 3D computer-animated openings for broadcast clients like NBC, ABC, CBS, and HBO. Only shortly before Henson's visit, though, had PDI begun to show what it could do in the field of character animation.

Of course, most computer-aided production houses are fairly new to character animation, due largely to the daunting problems posed by the undertaking. "First off, there are three major credibility issues in character animation," explains Glenn Entis, PDI Vice President of Production. "Does it look like the character? Does it feel alive? Does it feel like it's really in the scene? Those are major challenges we must meet time and again."

From the outset, it was clear that to make Waldo appear as if he "really" were in a scene, the project would require not only animation of the highest caliber, but also real-time feedback for

Waldo's Muppeteer. The 4D/70GT seemed like a prime candidate for the job.

The Waldo challenge, as Henson presented it to PDI, was: (1) to develop the underlying technology, (2) to prove the technology's viability, and (3) to apply the technology during the heat of production. Lastly, the Waldo character, as created by Henson's Kirk Thatcher, was to have all the dynamics and wobbly characteristics of *Balloon Guy* (introduced at the 1986 SIGGRAPH) [Wedge86] — a tall order as PDI was soon to learn.

Resembling a cross between a bumble bee and a water balloon, the Waldo specified by Henson was to undulate in a "wobbulated manner" during his flights in and out of scenes. Also, all of the input for Waldo's movements was to be captured during actual performance — not simulated and cut in later. Henson was resolved that Waldo's motion would be obtained directly from a puppeteer's movements.

Adventures in Armatures

For Waldo to perform live, a special hand-operated *armature* had to be designed. Tom Newly of the Henson Puppet Workshop took on the project, producing an armature resembling an upside-down luxo lamp neck with a "clam shell" glove mounted where a lamp shade might otherwise be. Optical shaft encoders mounted on six joints of the contraption were rigged to translate Waldo's body movements to digital signals which then could be sent to the attached 4D/70GT. Two additional encoders were added to the clam shell to monitor Waldo's upper/lower jaw movements and facial expressions.

Operated like a hand-puppet, the armature first passed motion information to the workstation for processing and assimilation with a pre-generated description of Waldo's shape. A stiff, low-resolution, quickly-shaded version of Waldo then appeared on the Muppeteer's display. Simultaneously, through the magic of video switching, Waldo's image also materialized on a separate monitor, composited together with the video obtained of the other performing Muppets. All the while, Waldo's puppeteer, Steve Whitmire, could monitor the animated Waldo's appearance and determine how his movements synchronized with those of the other performing Muppets. Fellow Muppeteers, meanwhile, could watch another monitor to observe as their muppets interacted with Waldo.

To help Waldo perform most, if not all, of the tricks desired of him, PDI animator Rex Grignon was sent to the Muppet's studio in Toronto to act as technical director for the project. Besides answering technical questions, Grignon frequently was called upon to provide bits of secondary motion during live performances.

Bouncing Goop

Once Waldo's performance was complete, his data was sent back to PDI headquarters in Sunnyvale for a complete beauty treatment. Starting with the primitive images captured during the Muppet's live performance, anima-

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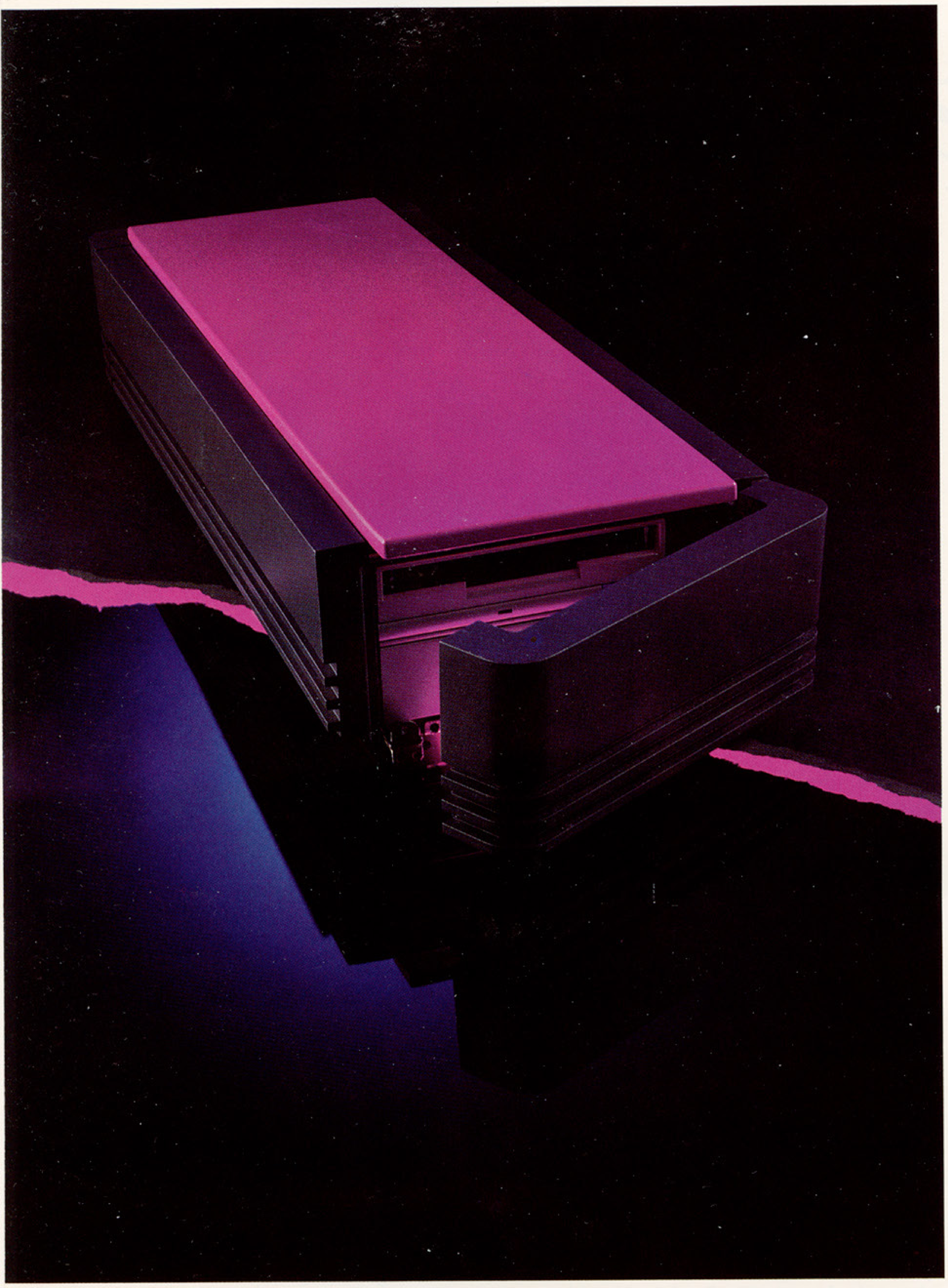

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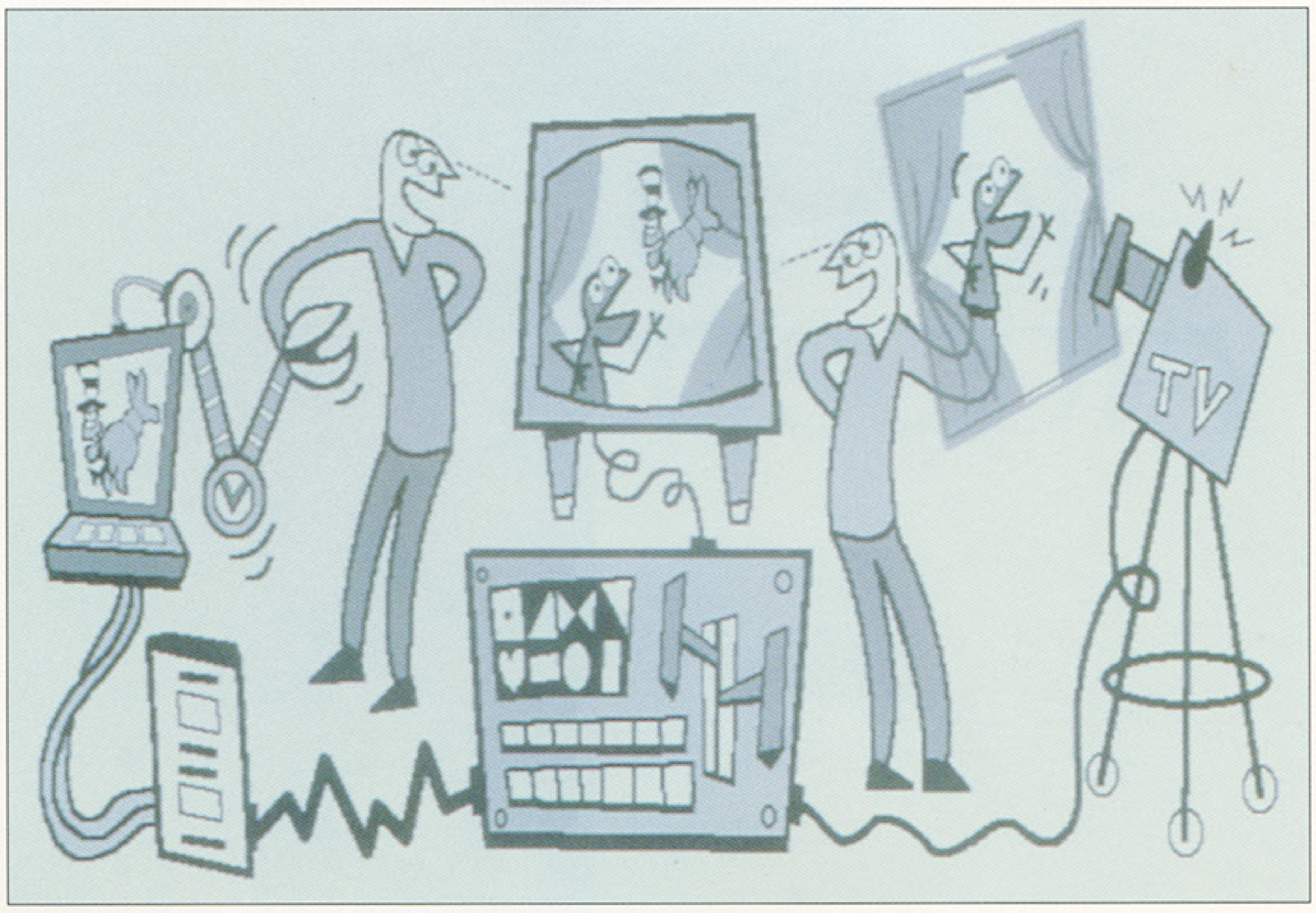
tors Michelle Tsui and Rex Grignon applied finishing touches that included such secondary animation elements as costume changes and flipper and wing movements. Among the roles assumed by Waldo during the series were those of a cowboy, a dinosaur, a doctor, a valley girl, and a circular saw.

Goopiness, the dynamic factor responsible for Waldo's water balloon-like quality, also had to be added. Graham Walters, the engineer who wrote Waldo's software, and Thad Beier, manager of PDI research and development, originally set out to duplicate the dynamics program used for *Balloon Guy* [Haum86]. In the course of their work, though, they found that numerical instability and modeling problems made the animation difficult. Says Walters, "My respect for Chris Wedge's work as the animator on *Balloon Guy* soared." Rather than tangle with similar demons, Walters and Beier decided to write their own dynamics program.

Working from the basic concept at the heart of *Balloon Guy* — to develop simple objects and determine how to build more complex things using those objects — the PDI team came up with its psuedo-dynamics goop program. Whereas the *Balloon Guy* approach incorporated a number of different motion properties, the goop technique simulates only one — that of a spring [Walters89].

By implementing this simplification, Walters and Beier made it possible for PDI's animators to use their standard approach to building objects: since they could add the spring function to *all* of the points in the object, they needed only to vary the parameters. Objects thus could be made gushy in some areas but somewhat more solid in others. Also, because each point was treated independently, the resulting images were completely resolution-independent, making it possible for objects to be designed at low-resolution and then rendered at high-resolution.



While the Muppeteer on the left manipulates an armature controlling the motion of the computer-generated Waldo, the Muppeteer on the right operates a hand muppet before a TV camera. The two images are then composited on a monitor so the Muppets can interact.

Equally important, Waldo's goopy constitution allowed the animators to discretely select the parts of his anatomy that were to wobble or lag behind. These they painted with a "goop map." For example, while a very bright map was built across Waldo's belly, a very dark one was laid across his back. By looking up these maps, the simulation could determine the belly was to be gushy and the back was to be kept stiff.

As animator Rex Grignon explains, "We took the basic Waldo and, by doing a couple of bounce tests, adjusted each part until it had the desired elasticity." Once this was correct and the required animation elements had been added, Waldo was all but ready. A final high-resolution rendering, produced on a gray background, had only to be sent to VTR Productions in Toronto for compositing into the finished show to at long last realize Henson's vision of an electronic muppet. Waldo had finally come to life. ■

Gaye L. Graves is a visual information specialist at NASA Ames Research Center. She also is a Bay Area ACM/SIGGRAPH officer whose involvement in national ACM/SIGGRAPH conference committee activities spans several years.

References

[Haum86] Dave Haumann, *Balloon Guy*, SIGGRAPH '86 "Physically Based Modeling" Course Notes (1986).

[Walters89] Graham Walters, *Waldo*, SIGGRAPH '89 "3D Character Animation by Computer" Course Notes (1989).

[Wedge86] Chris Wedge, *Balloon Guy*, SIGGRAPH '86 "Character Animation" Course Notes (1986).

feature

THE EVOLUTION OF ELECTRO-STEREOSCOPY

Recent advances in stereo viewer technology have moved the devices into the 3D computing mainstream.

BY LENNY LIPTON

There's a difference between what people in the field of computer graphics have come to call "3D" and what the rest of the population means when it says "3D." Common to both usages is the notion that a 3D image is more realistic than an ordinary one. But while people in computer graphics have used the term for many years to refer to images with shading and other depth cues such as perspective — that is, to differentiate solid models from wireframe renderings — the lay public understands a computer-generated 3D picture to be one that can be viewed like any object in the natural world, which is to say *stereoscopically*. True stereoscopic images present two, not just one, perspective views to the observer (see Figure 1).

Usually, we are unaware of seeing two images, even though we have two eyes offset horizontally by an average of about 2.5 inches, and so have two different views to process. If you could somehow freeze the images formed by the lenses on both eyes' retinas and overlay them, you'd see a double image, with portions of the two originals displaced horizontally. This horizontal difference between the two images, called *disparity*, is the physiological basis for the stereoscopic depth sense. If you've looked at a modern electronic stereoscopic display without viewing glasses, you've probably noticed that the overlaid left and right images look double, as would overlaid retinal images. The horizontal differences on the monitor screen, described as *parallax*, are analogous to retinal disparity. Later, I'll explain how the display interfaces with an observer, but for now let's concentrate on the depth sense, *binocular stereopsis*.

In some way, the mind uses disparity to create stereopsis, a depth cue distinct from any other because it depends on both eyes. Earlier, I mentioned a couple of the depth cues, perspective and shading, used in computer graphics to produce so-called 3D images. There are other monocular depth cues as well, including interposition (one object blocking another) and aerial perspective (the use of haze between the observer and a distant object). Another significant cue involves the rotation of objects to produce a motion parallax. All of these cues were understood as far back as the Renaissance, and all can be perceived using only one eye. Thus, a person looking at a modern computer graphics 3D display can get just as much depth perception with one eye covered as with both eyes open.

This is not to denigrate monocular depth cues, all of which strengthen the stereoscopic cue. But it does mean that when stereo cueing is added to a well-prepared 3D image, the appearance of the image will become even *more* realistic.

In the Beginning

The first person to realize that stereopsis was a separable depth sense was Sir Charles Wheatstone, who made the first stereoscope in 1833. Before Wheatstone, men like Euclid and da Vinci understood that each eye saw a different perspective view, although they weren't quite sure why. It was Wheatstone who turned the problem into a solution by demonstrating that the two retinal images provided the basis for a new depth sense. Because his work to develop stereoscopic imagery preceded photography, Wheatstone proved his point by creating the world's first stereo pair drawings.

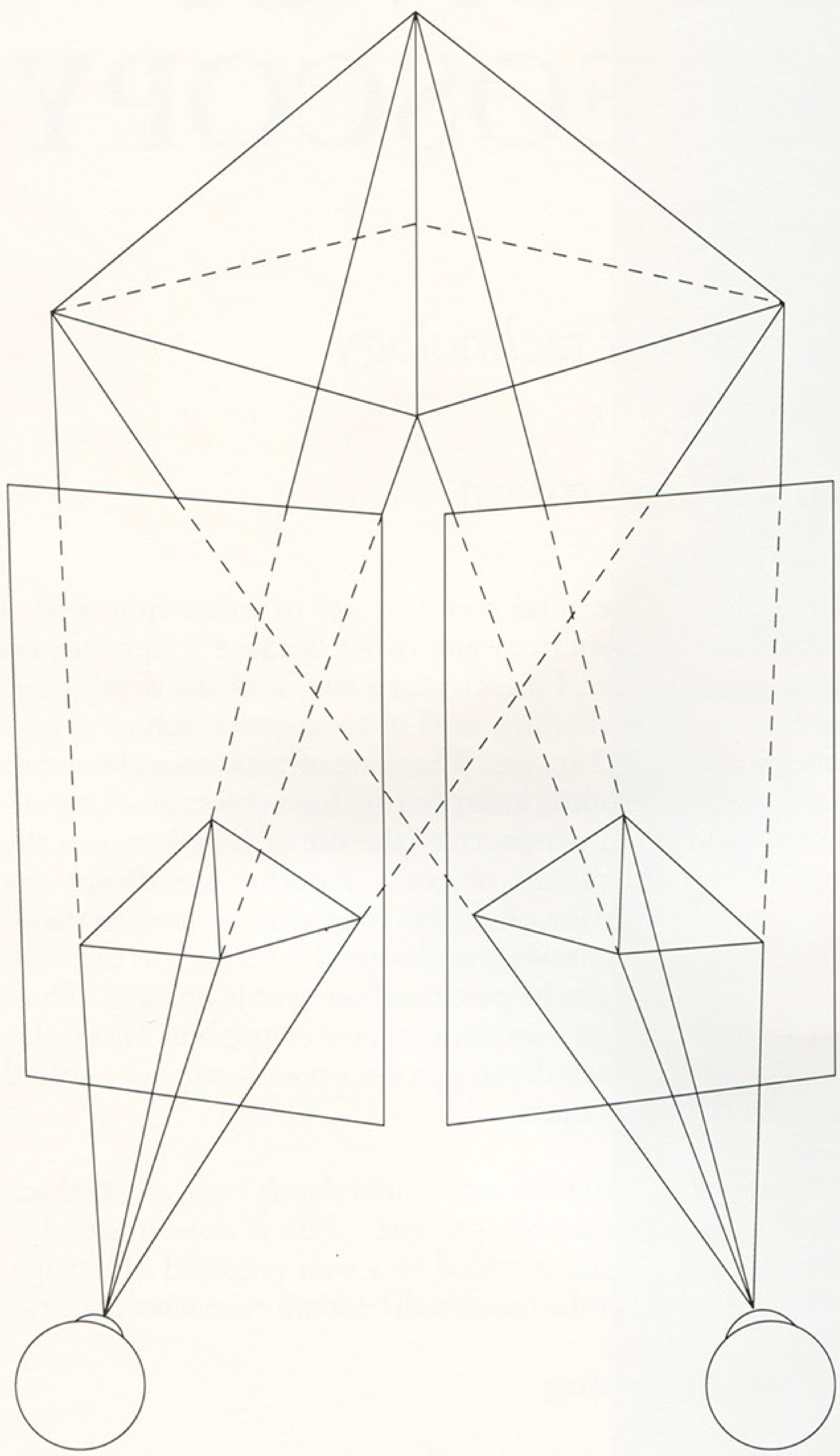


Figure 1: An illustration of two perspective points of view. The eyes, like a double-lensed stereoscopic camera, see objects from two perspective viewpoints. Shown here are geometric projections onto two plane surfaces of a three-dimensional object. (After Gibson, 1950). [Courtesy of Van Nostrand Reinhold]

Accordingly, people who today use electro-stereoscopic computer graphics displays actually are carrying on in Wheatstone's tradition since they too are drawing stereo pairs.

The stereoscope is probably the easiest of the true three-dimensional displays to understand. It requires only that two images be viewed side-by-side through two separate matched optical systems: one for the left eye and one for the right. Take as an example the plastic stereoscope included with this magazine. It uses two lenses to help your eyes focus on two small photomechanically reproduced images.

Modern Electro-Stereoscopic Displays

As pleasant as the stereoscope is, it has obvious limitations for many display applications. Most significantly, it's hard to imagine such an approach winning general acceptance for the viewing of images on a computer screen. Most people who use workstations are not about to put up with the awkwardness of looking through a stereoscope mounted on a display screen. Nevertheless, that approach *has* been tried. Another historic method involved the use of two "monitors" set at right angles, with sheet polarizers covering their screens. The viewer, using polarizing glasses, looked at the monitors through a semi-silvered mirror. Being both bulky and expensive, a contraption of this sort never would catch on as a workstation display.

With the advent of electro-optical shutters in the 1970s, though, an opportunity arose to make a decent field-sequential stereoscopic computer display. The left and right perspective views were alternately presented on the monitor, with shutters being used to segregate the images, one for each eye. The effect was to make it possible to display both images on a single monitor. The first such system, offered by Megatek in the late '70s, used PLZT ceramics for shutters and retained the usual 60 field-per-second refresh rate. PLZT electro-optics, though, are dim and require high voltage. What's more, using a 60 field-per-second refresh rate meant that each eye actually saw only 30 fields per second, resulting in a flickering image.

In 1981, StereoGraphics Corporation produced the first flickerless, field-sequential, electro-stereoscopic display by doubling the usual video field rate. Because the critical flicker frequency for a bright computer display is about 60 fields per second for most observers, stereoscopic computer images must be refreshed at least 120 times per second. This

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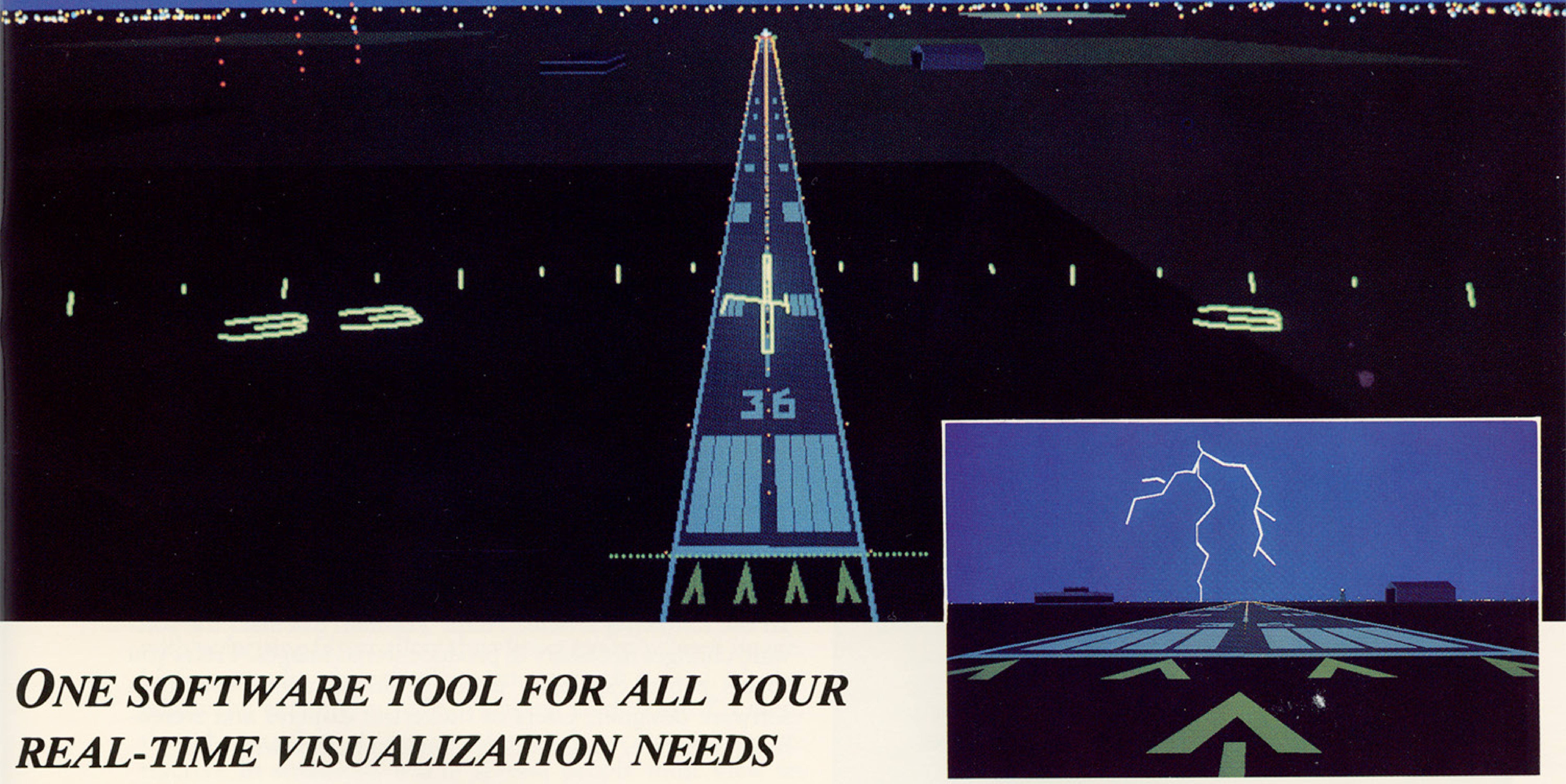

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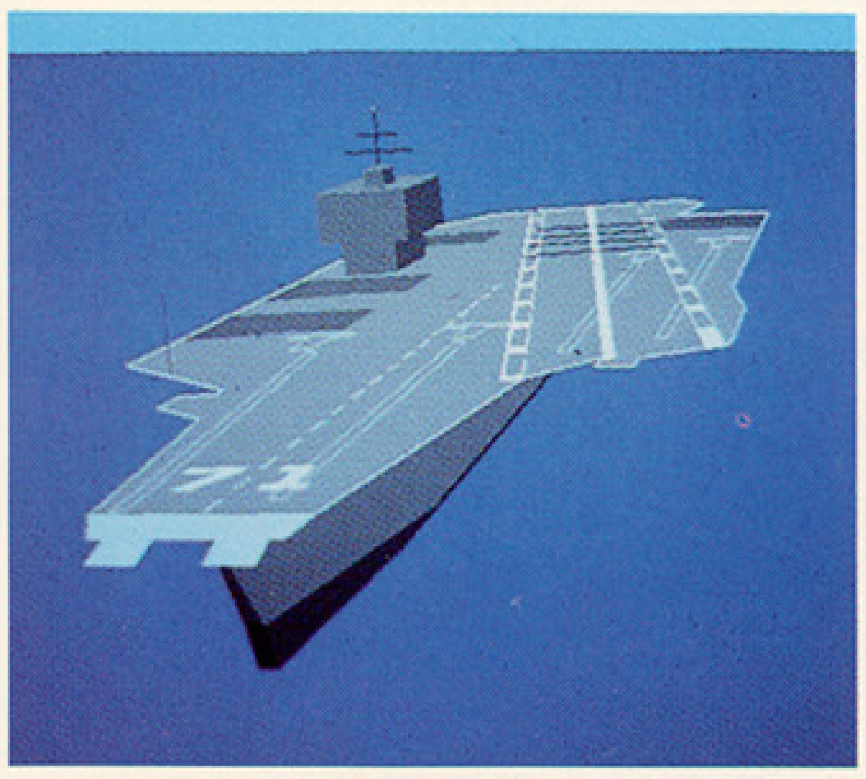

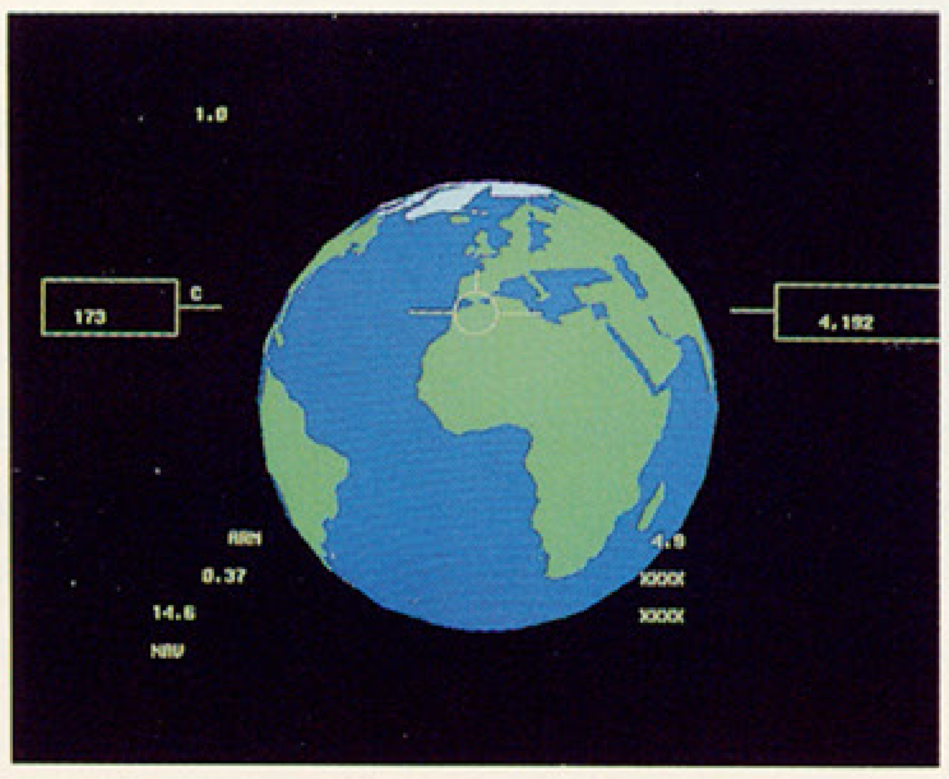

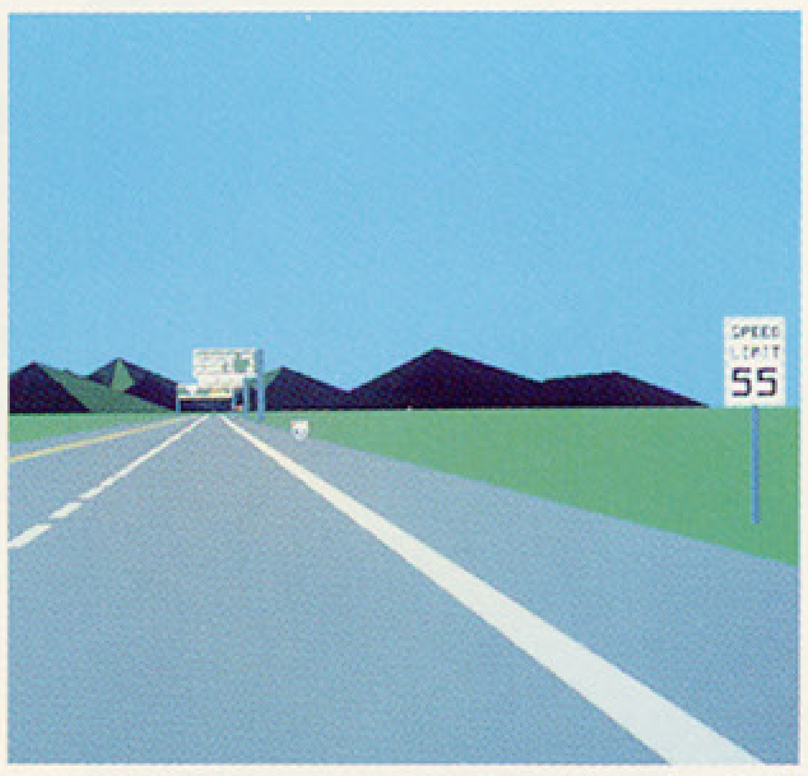

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allows each eye to see a flickerless 60 fields per second, mapping to a high-quality stereoscopic image. Right now, only Mitsubishi makes stereo-ready monitors capable of operating at either 60 or 120 Hz, but several other manufacturers are expected to offer similar products by next year.

The flickerless display is very much like a typical planar (non-stereo) display, the principal difference being that users must wear a "selection device" (glasses) to see the stereo effect.

Software for Stereo

In the following article, Thant Tessman discusses the software changes necessary to produce stereo images. I refer you to his paper, especially if you're an advanced user or a software designer. Users of flickerless displays and stereo-ready software, though, don't have to bother with this.

With no more effort than it takes to produce the usual planar 3D image, these users can produce a true stereo 3D image. Creative controls built into stereo-ready packages, moreover, make it possible to vary stereo effects. At least 15 vendors of 3D software have already added stereoscopic capabilities to their packages. Others will follow suit.

Raison d'être

Why stereo 3D? In a word, "visualization." It's easier to visualize stereo 3D images than to visualize ordinary, planar screen images or wireframes.· Seen in stereo, the volumetric or spatial extent of 3D objects and the way in which they interrelate are easier to understand. This is why people in molecular modeling have used crude stereo systems with spinning mechanical shutters for years. They've known that to really see molecular structure they must either use a stereo display or build models. On the whole, stereo viewing is easier.

Stereo viewing has also been in use for years in other fields, including aerial mapping, where stereo has been used chiefly to perform height measurements. In the past, manual stereoscopic methods were used to view photographs, but aerial mapping has since migrated to computer-enhanced and displayed images that require electro-stereoscopic techniques.

Meanwhile, in the design field, a vast and virtually untapped application for electro-stereoscopy exists. The opportunity this represents is enormous since, by adding stereo viewing, almost any design can be improved and made easier to understand.

The Latest Advance

For most users, two similar paths can be taken to electro-stereoscopy: the *ZScreen*™ and SGI's new *StereoView*™ product (this latter item is sold and supported by StereoGraphics as *CrystalEyes*™). The ZScreens, which have been shipped for three years, have become an accepted part of the way many X-ray crystallographers and computational chemists do their jobs.

The ZScreen is a large liquid crystal (LC) panel that changes the characteristics of polarized light at video field rate. All of the polarization is supplied by the ZScreen, since CRT displays don't produce polarized light. Appropriate glasses with polarizing filters allow the viewer to see a stereo image. Unfortunately, while the ZScreen approach is good, it's also relatively expensive. The glasses used with ZScreen, though, are relatively inexpensive, so this option may be attractive in situations where several people must view an image simultaneously.

StereoView takes the cost of the expensive liquid crystal out of stereo viewing by providing shuttering lenses in the eyewear itself. While the glasses use less than eight square inches of LC, the ZScreen employs almost 400.

StereoView works together with an infrared (IR) emitter (located near or on the monitor) that broadcasts synchronization information over a full hemisphere. The eyewear itself uses achromatic LC lenses with exceptionally good optical properties, and it uses a built-in IR sensor to receive the IR broadcast by the emitter, thus allowing the lenses to keep in sync with video fields as they are written. Two small, readily available lithium batteries loaded into the eyewear can power the unit for 200 hours of continuous use, and yet they make the total package only half again as heavy as normal glasses.

The technological advances incorporated into StereoView serve to underscore just how far electro-stereoscopy has come since the first dim, flickering PLZT system images. No wonder the technology now is being used on a daily basis by hundreds of people in a variety of computer imaging fields. Someday, it may even become the preferred method for viewing 3D images of *every* stripe. ■

Lenny Lipton is the Chief Technical Officer of StereoGraphics Corporation, which he founded in 1980. Among his inventions are the multiplexing technique essential to flickerless stereoscopic displays and the achromatic liquid crystal lens used in StereoView. Lipton also authored Foundations of the Stereoscopic Cinema *(Van Nostrand Reinhold, 1982).*

feature

PERSPECTIVES ON STEREO

Historically, we have relented too easily to the limitations of 2D displays. It needn't always be so.

BY THANT TESSMAN

Computer displays are inherently two-dimensional. Thus, to convey the three-dimensional information needed to solve some of our most perplexing scientific and engineering problems, computers must use techniques such as perspective, motion, intensity attenuation, and hidden surface removal to convey a sense of depth.

As detailed in the previous article, another important source of depth information can be conveyed if two spatially different views of the same scene are available. In "real life," the brain doesn't actually *see* double images. Instead, it converts the horizontal discrepancies into a sense of depth, known as *stereopsis* (from the Greek word *stereos*, meaning "solid").

The process is a fascinating one: when looking at an object, the sightlines of the two eyes cross, meeting at the point in space occupied by the object. While the eyes are thus focused, a closer object appears slightly shifted to the left for the right eye, and to the right for the left eye. Things lying beyond the point of convergence will appear to be shifted to the right for the right eye, and to the left for the left eye.

To take advantage of the brain's ability to achieve stereopsis, a computer must generate a separate image for each eye, using two slightly different viewpoints. The means for accomplishing this depends on how the scene is projected onto the screen (or screens), and on the way in which the images are presented to the eyes.

A separate image could be sent to each eye using two screens configured through some arrangement of lenses or mirrors, or through the use of very small screens. Approaches of this sort, though, are quite expensive and often require that the position of the viewer's head be restricted.

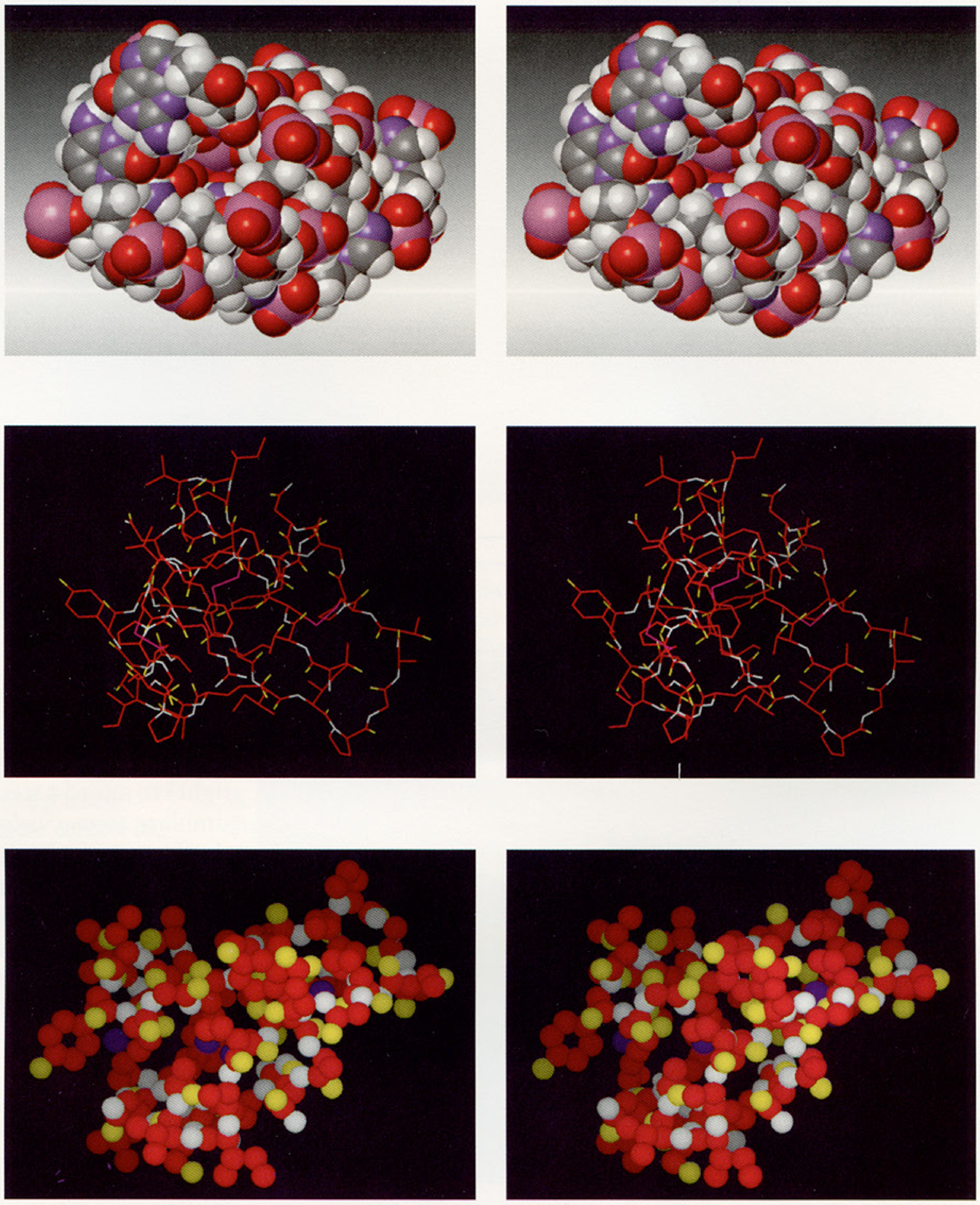
Another solution is to use one screen to display both images. With the left and right views being alternately displayed in rapid succession, a selection device can be used to separate the images for the two eyes. Thus, each eye is presented only with the image intended for it.

Silicon Graphics' StereoView 3D glasses, in combination with an IRIS 4D workstation, offer an inexpensive solution to the problem of presenting three-dimensional imagery on a single screen.

An image generated for the left eye is rendered in the upper half of the display (from 532 to 1279 pixels in *y*) and the image for the right eye is rendered in the lower half of the display (from 0 to 491 pixels in *y*). Each image has an aspect ratio of 1:2, and so appears anamorphically compressed in the vertical direction.

Viewed on a standard 60 Hz monitor, the screen appears as illustrated in Figure 1. When the refresh rate of the monitor is doubled to 120 Hz, only half of the 60 Hz display is used for each refresh. The halves alternate in a left/right/left/right (top/bottom/top/bottom) sequence, each image filling the screen in its turn. The monitor stretches the vertical height of each frame to proper proportions.

A pair of liquid crystal shutters mounted in glasses worn by the viewer alternately shut and open in synchronization with the monitor's refresh rate so that each eye sees



Images created using Biosym and MOLCAD software.

Molecular modeling packages often use orthographic projections, which generate stereo pairs by way of rotations. In these three pairs, the left and right views are separated by a seven-degree rotation.

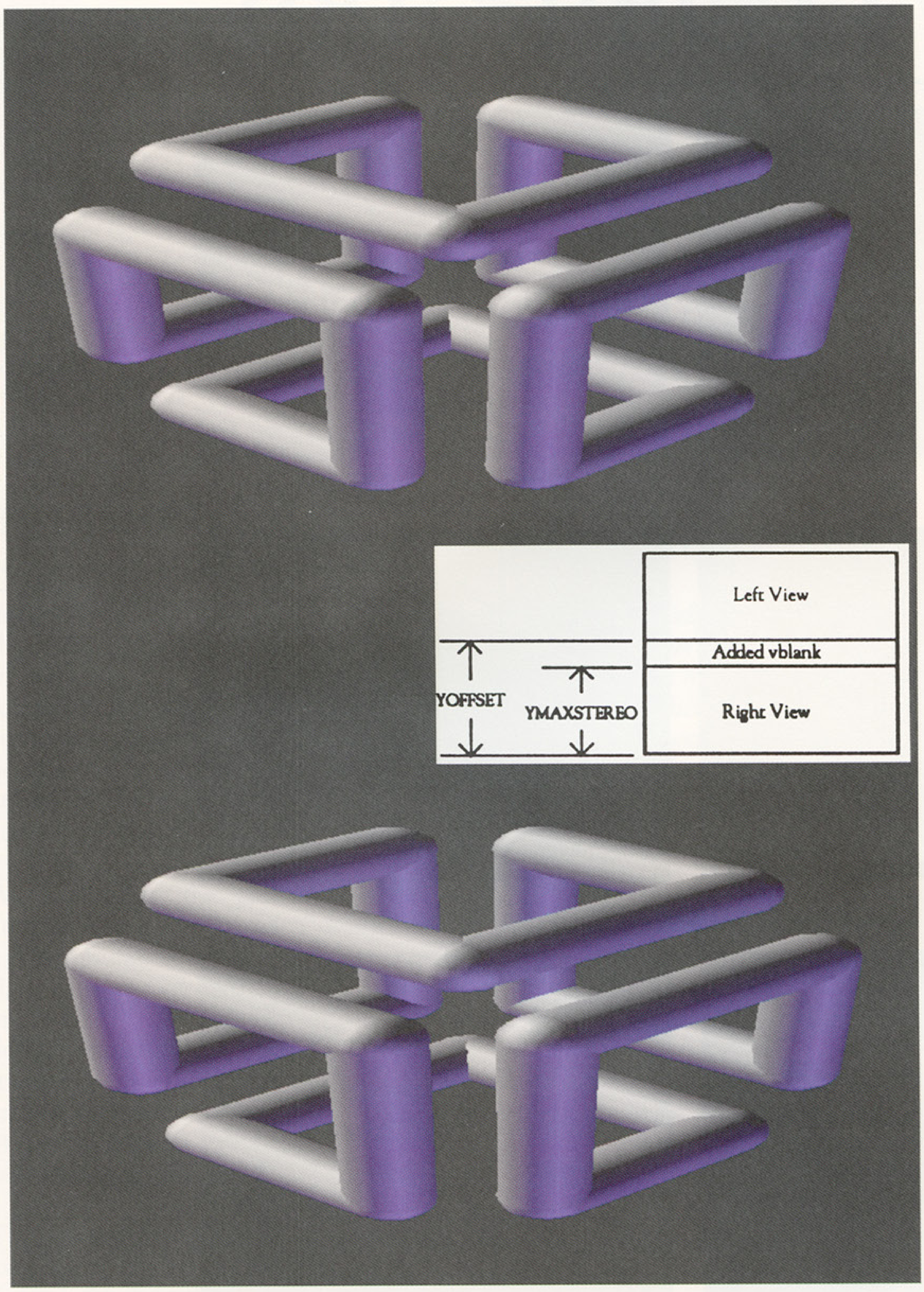


Figure 1: A stereo pair, as viewed on a monitor in 60 Hz mode (not stereo). The upper half of the display is used to provide the left view and the lower half is used for the right view. Each view is YMAXSTEREO pixels high, with the left view being set YOFFSET pixels above the right. (See program sample stereo.h *at the end of this article.)*

every other field. Because the refresh rate of the monitor is double the normal 60 Hz, each eye still sees 60 frames a second and so perceives no flicker.

Major software changes needn't be made to existing programs to take advantage of stereo hardware, but the *correct* projections and transformations aren't obvious. The significance of this is that stereo done incorrectly will not only be ineffective, but probably genuinely uncomfortable for the viewer.

Because our eyes cross to simultaneously point at something close, one common means for achieving stereo on a two-dimensional monitor is to rotate an object around its center, thus simulating two viewpoints converging on the object's center. Typically, the viewer's eyes will be about two feet (60 cm) removed from a monitor. Given that the average pair of human eyes is separated by 64 mm, an object viewed at this distance will require the eyes to cross by about six degrees (+3 around the up axis for the left eye, and -3 for the right) to afford a stereoscopic view. To simulate stereo vision on a monitor, a similar transformation is implied.

There is a problem with this approach, however. The perspective transformation projects 3D coordinates onto a plane perpendicular to the eye at the center of the plane. The farther a projection falls from the plane's center, the more stretched the image will appear. Showing the image on a flat screen will automatically compensate for this because the viewer can always see the screen itself in perspective. Moreover, the brain can compensate somewhat for the distortions caused when an image is projected onto a screen not perpendicular to the viewer's eyes — as is evidenced every

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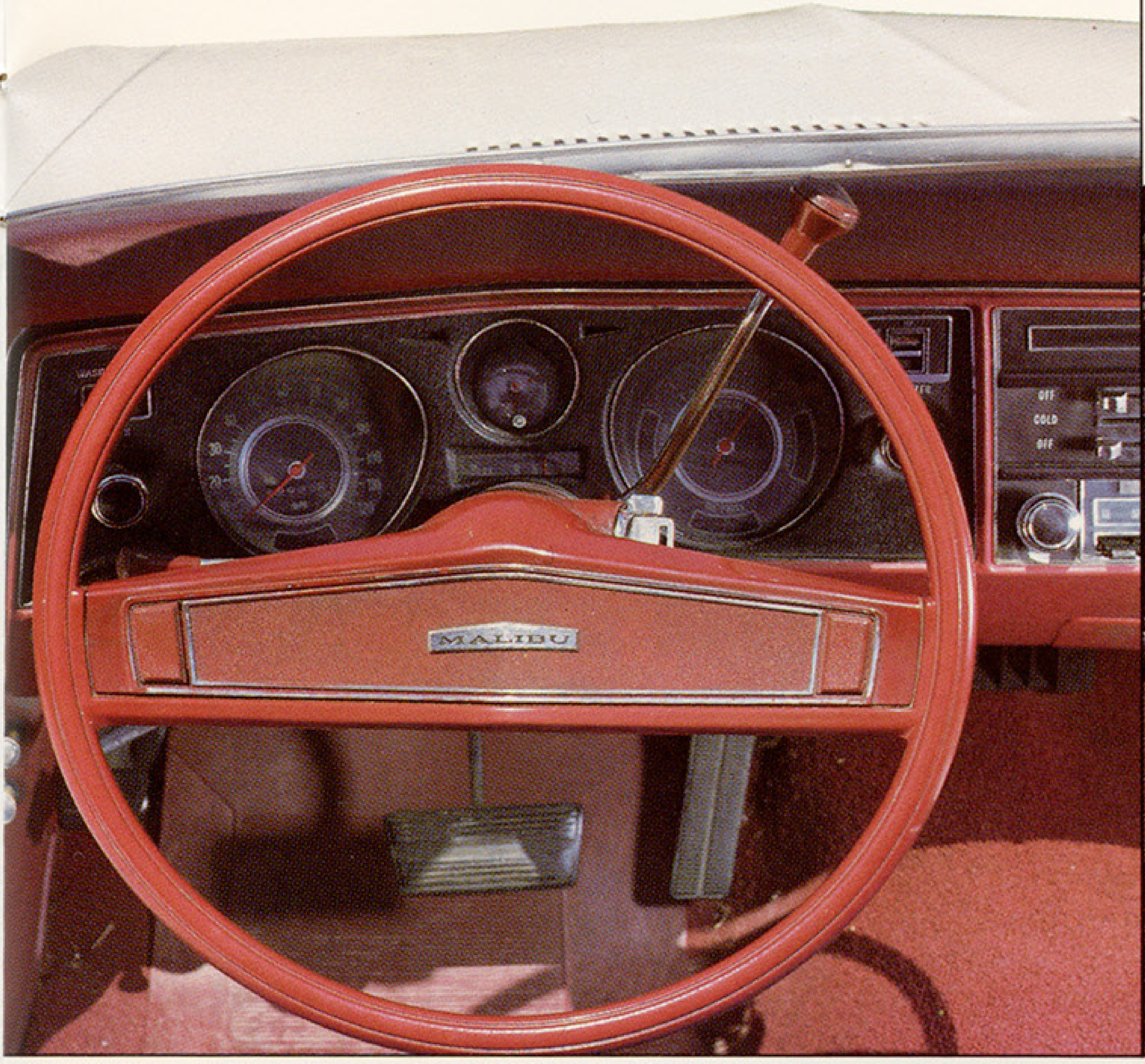

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time one is forced to take a seat away from the center of a movie theater. Such compensations are only possible, though, if the distortion is the same for both eyes.

If rotation is used to achieve different views, the projection planes of the views won't be parallel to each other. This isn't a problem if two separate screens are used, since they can be arranged to match the angle between the views. If only one screen is used to display both views, however, the distortions caused by the projection will be different for each eye. Everything to the left of the left view will be larger than in the right view, and the opposite will be true of everything to the right of the right view. The resulting distortions will be vertical as well as horizontal — a major problem since vertical parallax doesn't occur with normal vision and is quite uncomfortable for most viewers (see Figure 2).

One solution is to avoid using perspective, opting instead for orthographic projections, in which objects maintain a constant size as they move closer or farther away. Mathematically, it's as if the eye were infinitely distant. Rotations about the up axis cause only horizontal parallax.

Although this solution is fundamentally incorrect, it does work, it isn't uncomfortable, and so is commonly used in applications like computational chemistry that usually don't apply perspective. In fact, a rotation is the *only* easy way to achieve stereo using an orthographic projection. Examples are shown at the beginning of the article.

For perspective, the trick is not to rotate the scene, but to translate it to the left for the right eye and to the right for the left eye. Perspective will cause the closest objects to be the ones that are translated. (Note that this won't work with an orthographic projection because everything in the image will be translated by the same amount.) (See Figure 3.)

Notice, however, that scene translations alone aren't enough to achieve true stereopsis because projection planes move along with the eye. The planes are both parallel and co-planar, but are offset from each other. Often, the viewports or windows used to display each image can be shifted to compensate for this, but a better solution is to move the actual edges of the projection plane. (See Figure 4.)

The SGI Graphics Library offers the **window** command for accomplishing just such off-center projections. The near clipping plane serves as a window that can be thought of as the "screen" for scene projections. To make it appear that the user's view has shifted to the right, the scene and the edges of the projection plane can both be translated to the left. Conversely, for a view shift to the left, the scene and the projection plane edges can be translated to the right. This guarantees that each view will be projected onto the same plane from the two viewpoints. Any part of the scene co-planar with the projection plane will have the same *x* coordinate regardless of the user's viewpoint. Accordingly, this plane is known as the "plane of convergence."

Some prefer to think of projections in terms of the **perspective** command. The **stereopersp** command is exactly alike, except that it offers two additional useful parameters. The *conv* parameter allows one to specify the distance from the eyes to the plane of convergence. Setting *conv* to the value of the near clipping plane is equivalent to using the **window** command in the way just described. The **stereopersp** *eye* parameter, meanwhile, sets the distance at which the viewpoint is to be translated from the center line (usually accounting for just half of the eye separation). The value should be positive for the right view and negative for the left. (See the code and associated stereo pair on the facing page.)

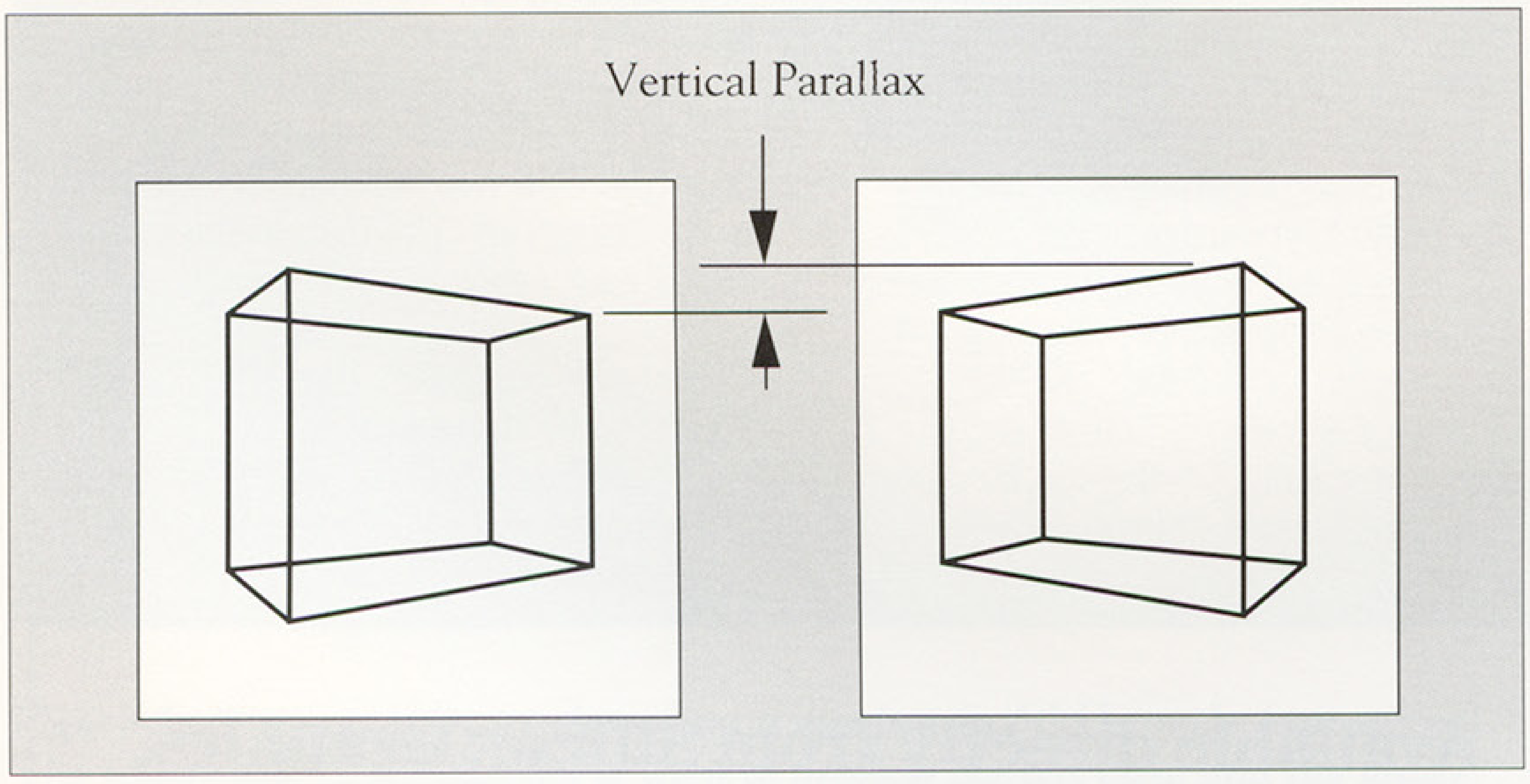
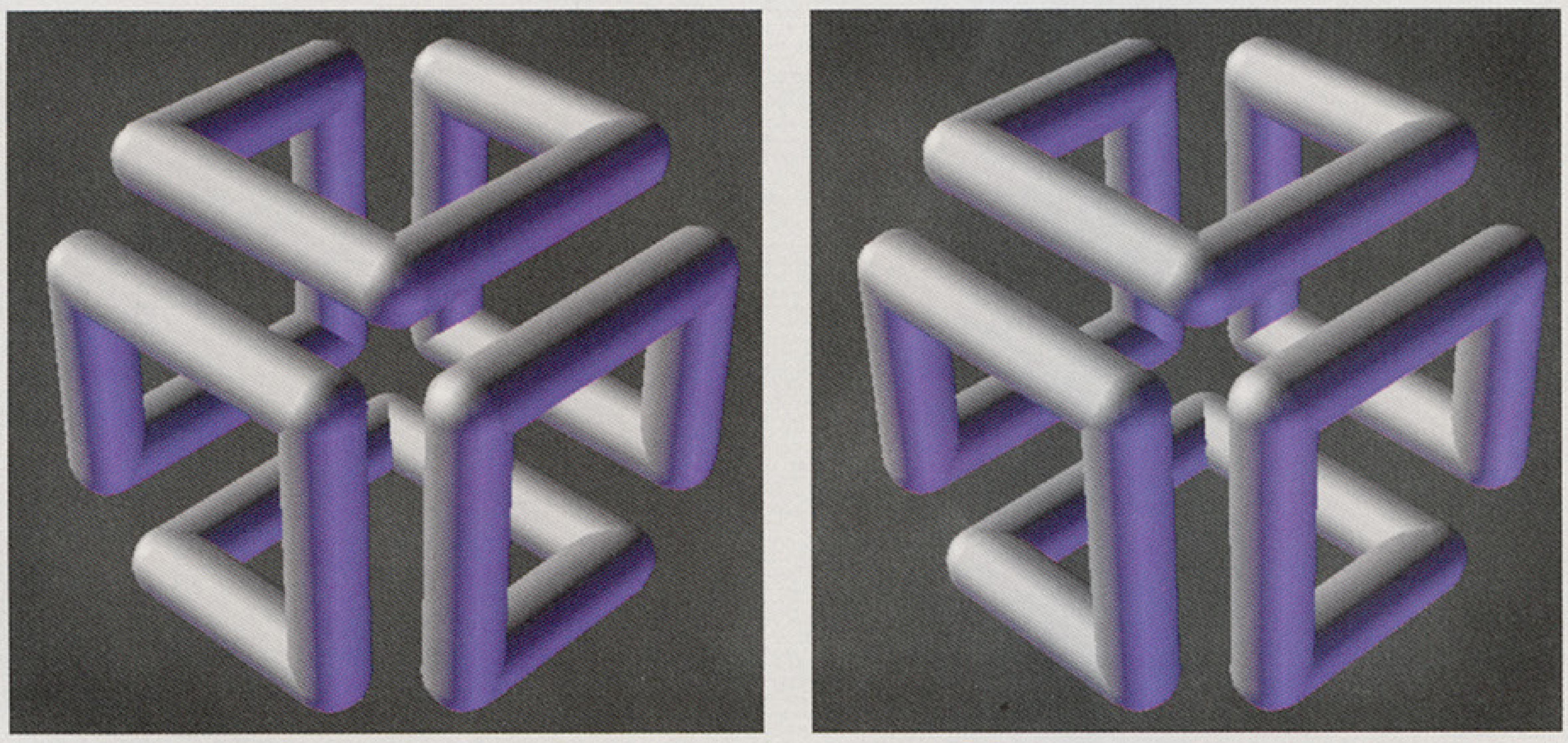


Figure 2: Using rotations with perspective causes vertical parallax. The forward upper right corner of the cube shown here is at a different height for each image.



```
/*  stereo.h*/

#ifndef  STEREO_H
#define  STEREO_H

#define  YMAXSTEREO  491
#define  YOFFSET  532

extern void stereopersp (int, float,
float, float, float, float);

/ * stereopersp (fovy, aspect, near, far,
  * conv, eye)
  *
  * fovy, aspect, near, far - all work
  * just like the 'perspective' command
  *
  * conv - the plane at which the left and
  * right image will converge on the
  * screen. If conv is equal to the near
  * plane, the stereo image will appear to
  * be behind the plane of the screen. If
  * conv is set to the far plane, the
  * stereo image will appear in front of
  * the screen.
  *
  * eye - the distance (in world
  * coordinates) that the eye is off-
  * center (half the eye separation).
  */

#endif
```

```
/*  stereo.c*/

#include  "stereo.h"
#include  "math.h"

extern void translate(float,  float,
float);
extern void window(float, float, float,
float, float, float);

void stereopersp(fovy, aspect, near, far,
conv, eye)
int fovy;
float aspect, near, far, conv, eye;
{
  float left, right, top, bottom;
  float gltan;

  gltan  =  tan(fovy/2.0/10.0*M_PI/180.0);

  top = gltan * near;

  bottom =  -top;

  gltan  =  tan(fovy*aspect/2.0/10.0*M_PI/
  180.0);

  left  = -gltan*near  -  eye/conv*near;
  right  = gltan*near  -  eye/conv*near;

  window(left, right, bottom, top, near,
  far);
  translate  (-eye, 0.0, 0.0);

}
```

The stereopersp *command and a stereo pair that was generated using the program.*

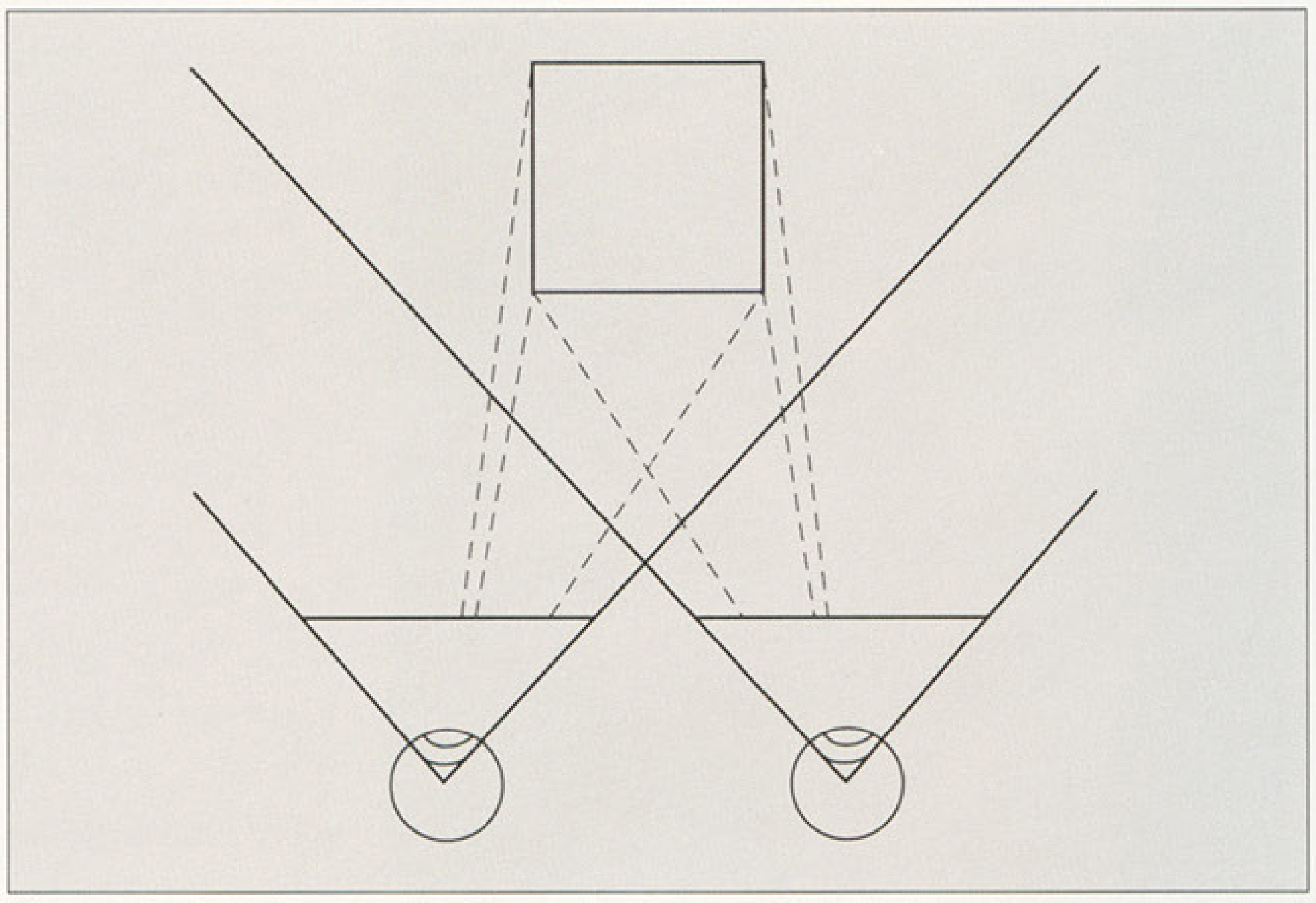


Figure 3: Using translations and perspective guarantees that the projection planes will remain parallel.

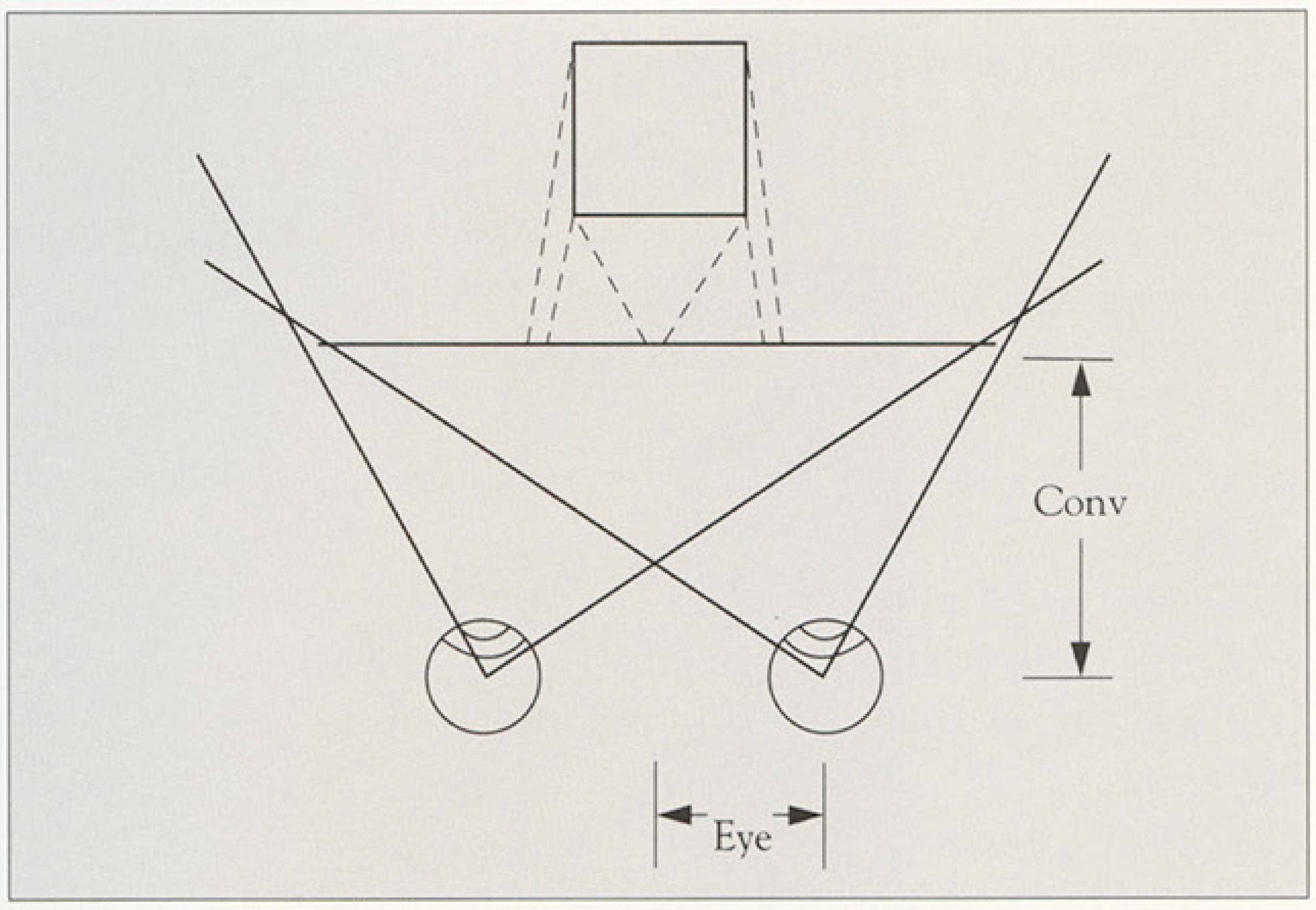


Figure 4: Two separate views can be projected onto the same plane by using an off-center projection.

Hints

Our brains are quite flexible, so the amount of perspective and eye separation to account for in producing a stereo image are to some degree a function of taste. Although a major source of eye strain can be eliminated by using the **window** command or the **stereopersp** command, users of these commands still must adhere closely to a few guidelines to achieve the desired results.

Objects in an image that are intended to appear closer than the convergence plane will seem to be in *front* of the screen, while things beyond the convergence plane will appear to be submerged in the recesses of the monitor. If *conv* has the same setting as *near*, everything will appear to lie beyond the screen. Conversely, if *conv* is set to *far's* value, the object shown will appear to stand in front of the screen. If *conv* is set somewhere in between — to the value that corresponds to the center of the object, for instance — the object will appear to rest right at the surface of the screen. This typically is ideal.

Images can be safely clipped by the upper and lower edges of the stereo view, but some care should be taken to see that objects aren't clipped by the side edges. No problem should arise if the objects are drawn beyond the projection plane since they'll merely appear as if they're being viewed through a window and are thus framed within the window's boundaries. Things, though, shouldn't lie in front of the projection plane if they're to be clipped by the side edges since the human mind doesn't know quite what to do with objects that stand in front of a window frame and yet are occluded by it.

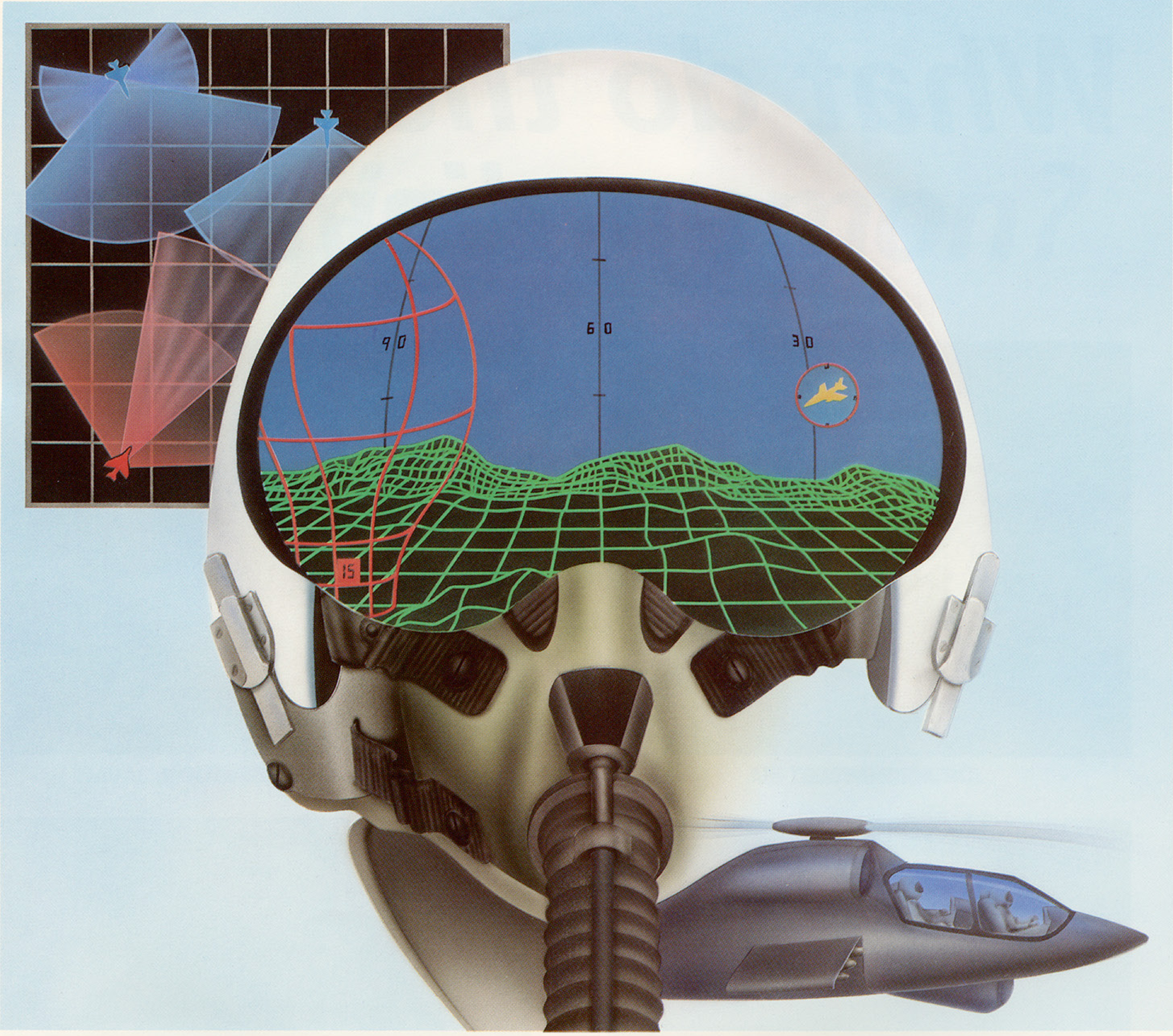
The closer a projection's field of view comes to matching the angle subtended by the display (about 30 degrees for the whole screen), the more it will appear as if the object is floating just inside the monitor.

Eye separation is reflected in the scene's coordinates. As the spread between the eyes grows, so will the separation; as the stereo separation grows, the object will appear smaller. Hence, with excess eye separation, a large city can be made to look like a table-top model. For similar reasons, providing an eye separation of 64 mm for a view of a molecule only a few angstroms wide probably would be inappropriate. A realistic eye separation should be chosen on the basis of how "large" an object needs to appear in order to be usefully manipulated.

Conclusion

Historically, we have given in far too easily to the limitations of two-dimensional displays, treating stereo as a fringe technology useful only for specialized fields, bad movies, and toys. Now, though, StereoView from Silicon Graphics and improving stereo techniques are conspiring to reduce the price and increase the quality of stereoscopic displays. As a result, the use of stereo may soon become a common means for addressing and solving everyday scientific and engineering problems. ■

Thant Tessman is a Silicon Graphics systems engineer working in the company's Advanced Systems Division..



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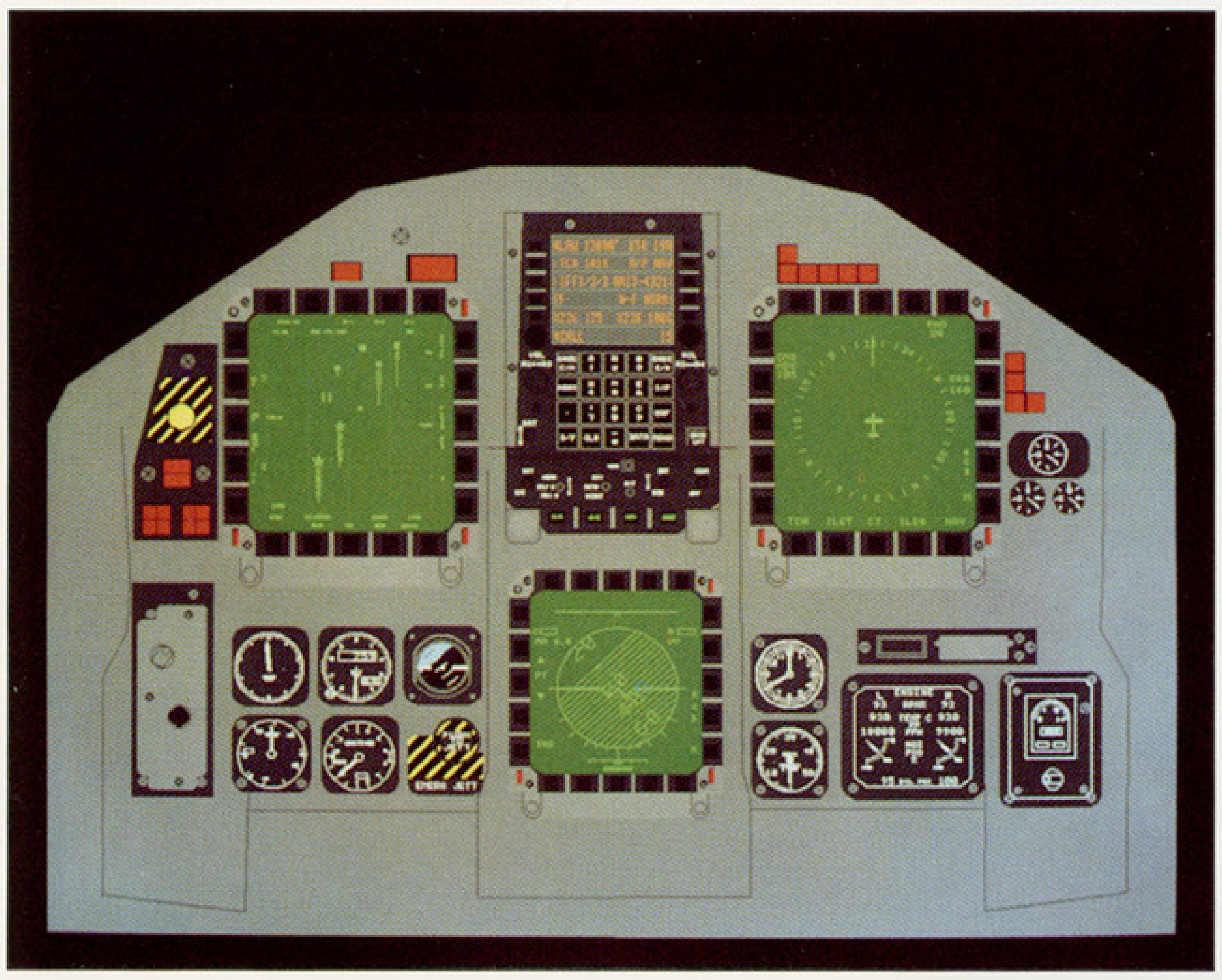

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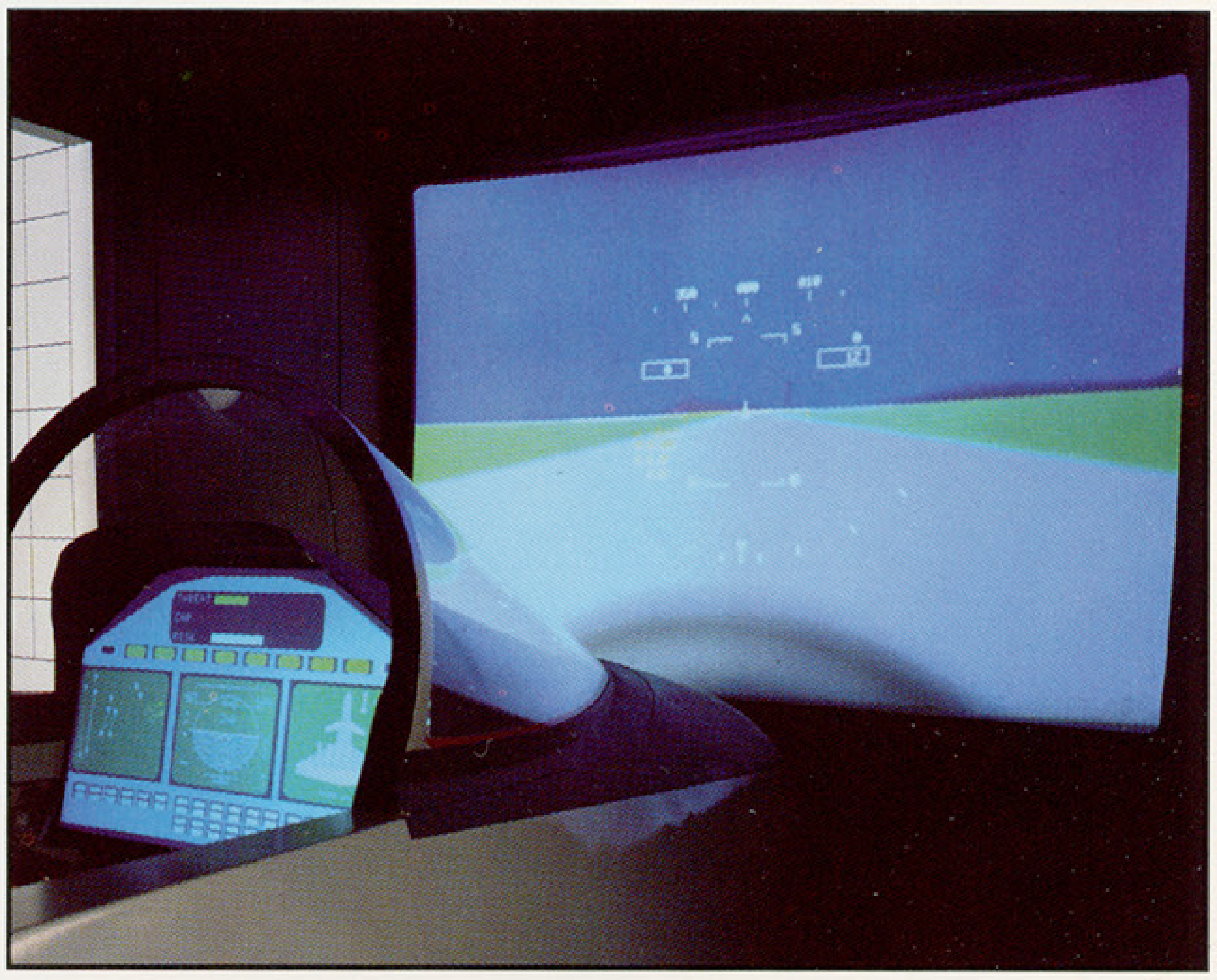

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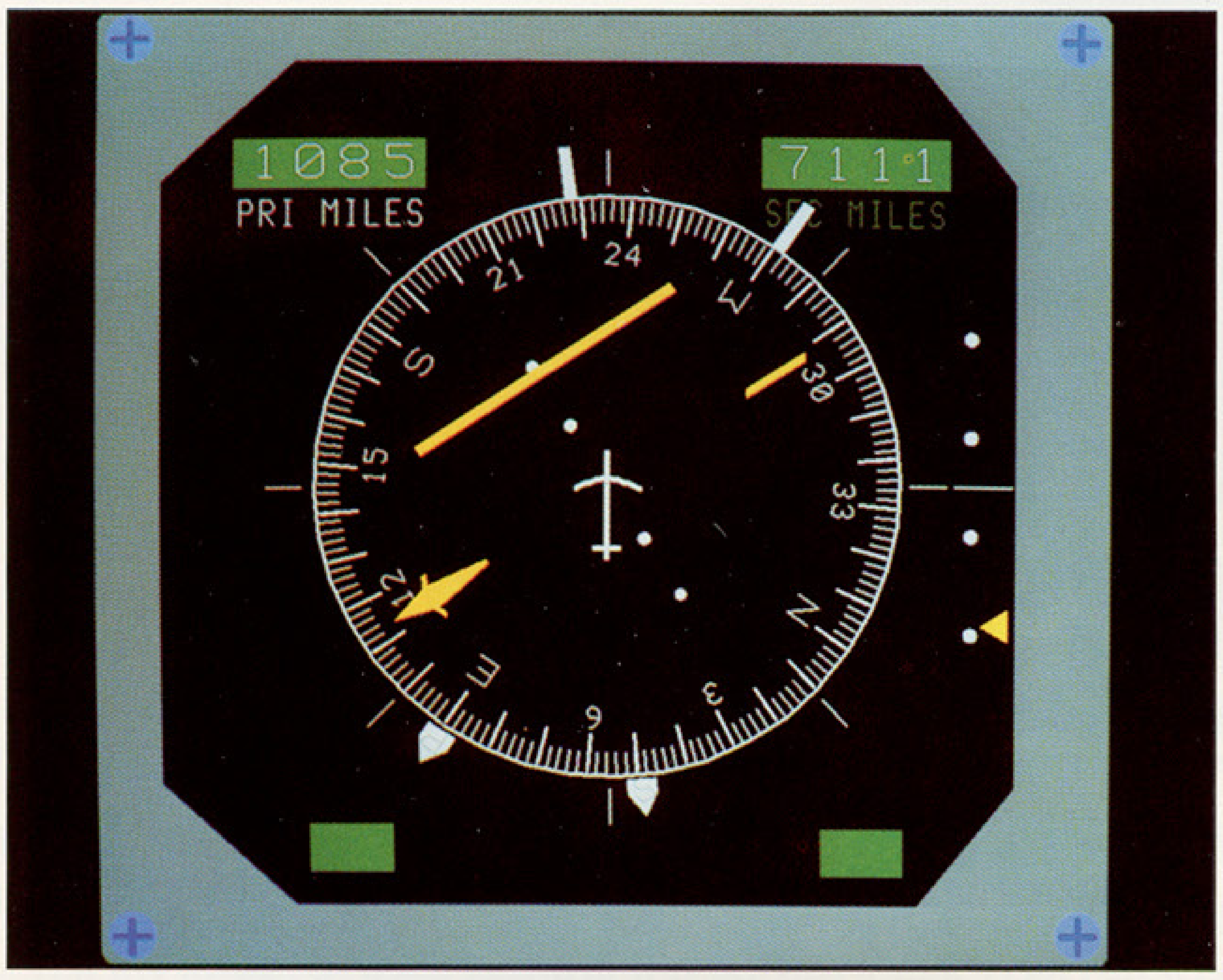

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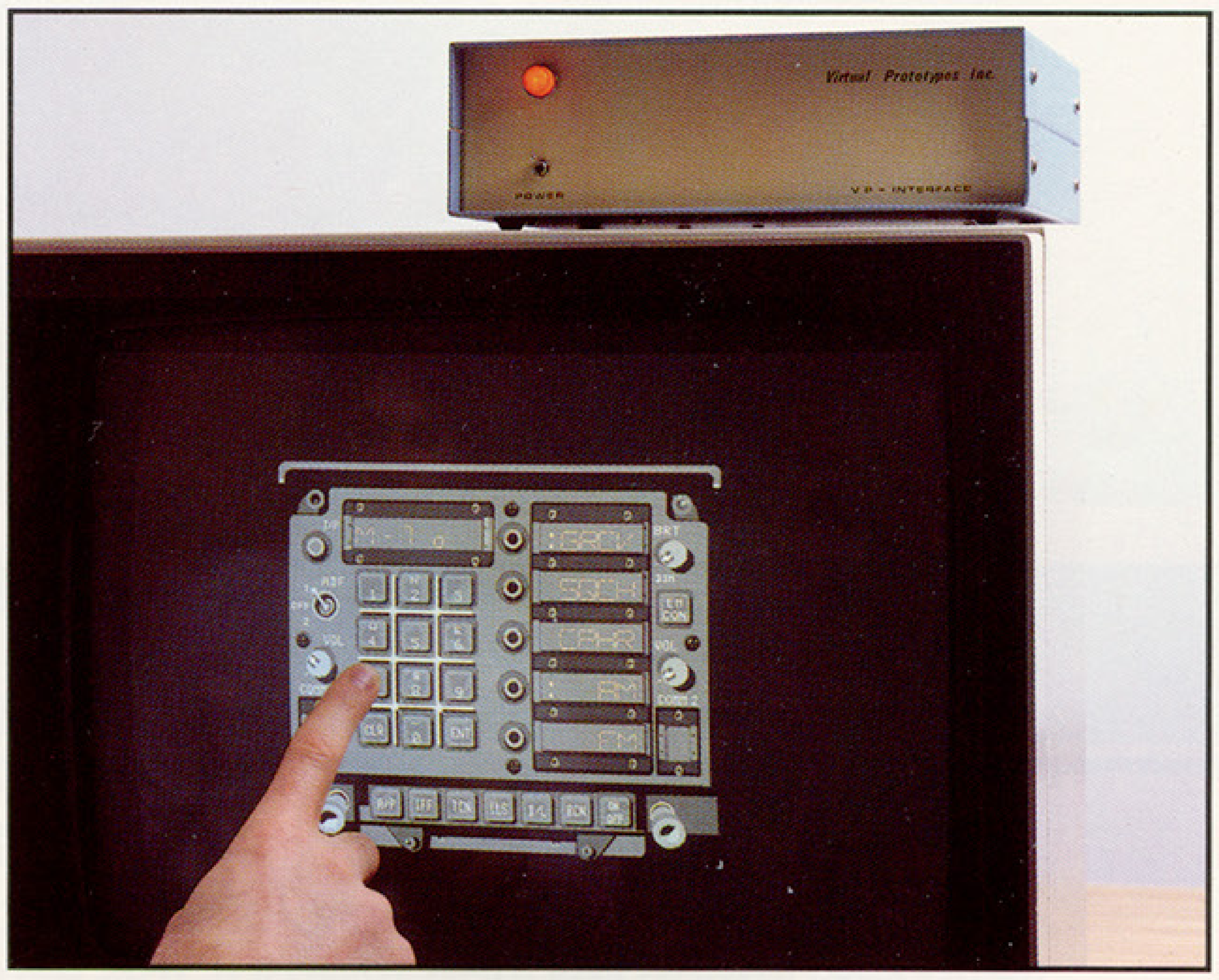

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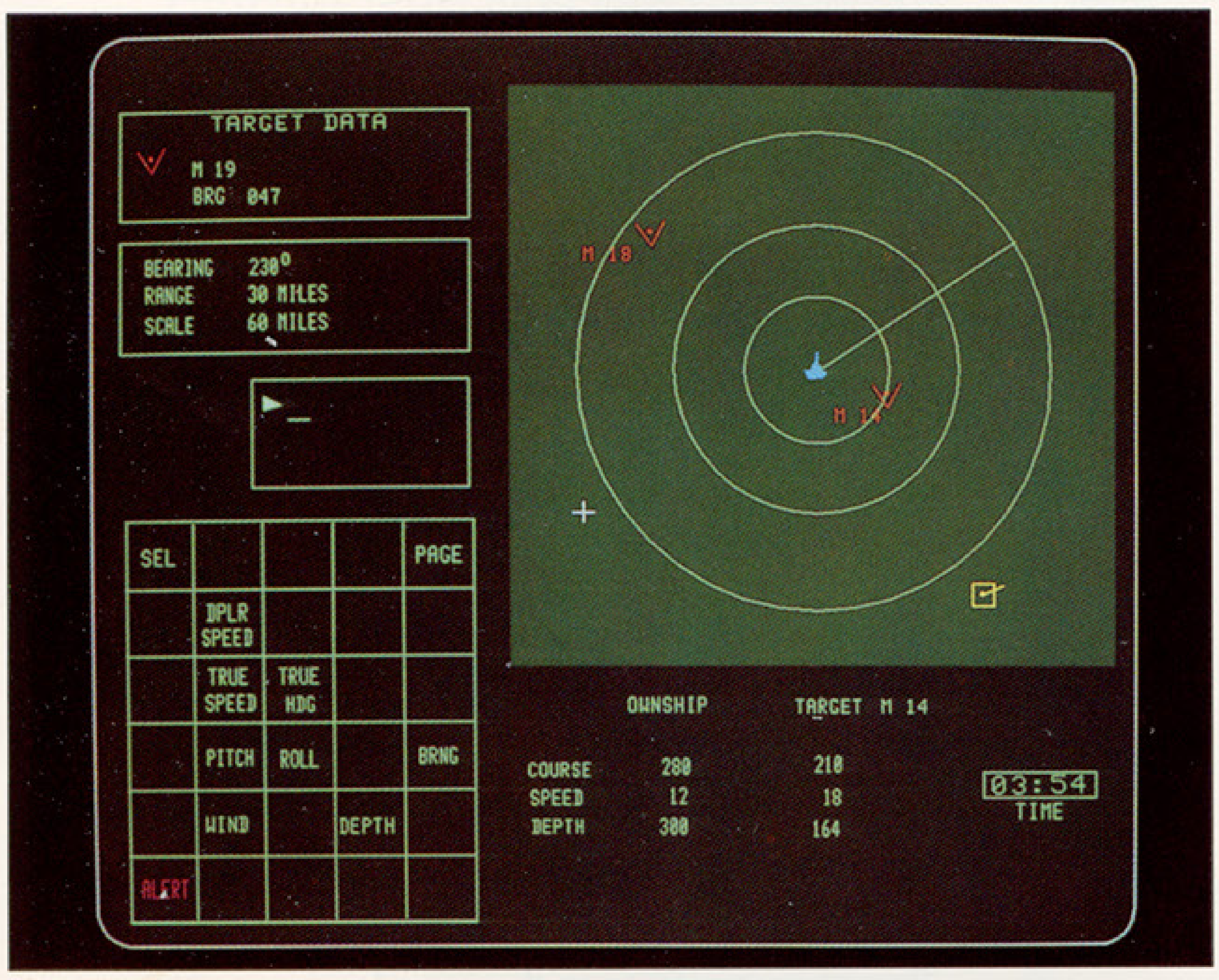

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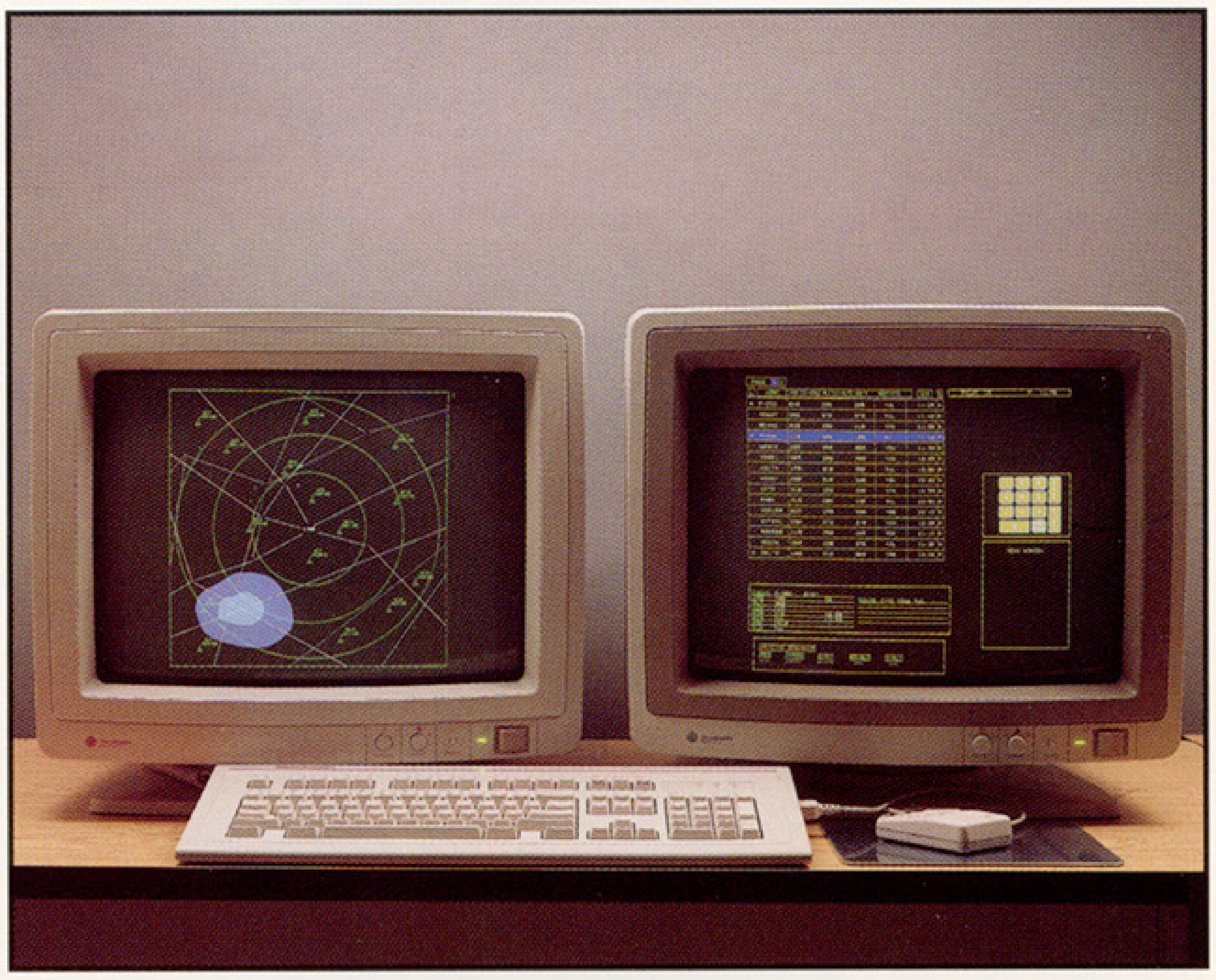

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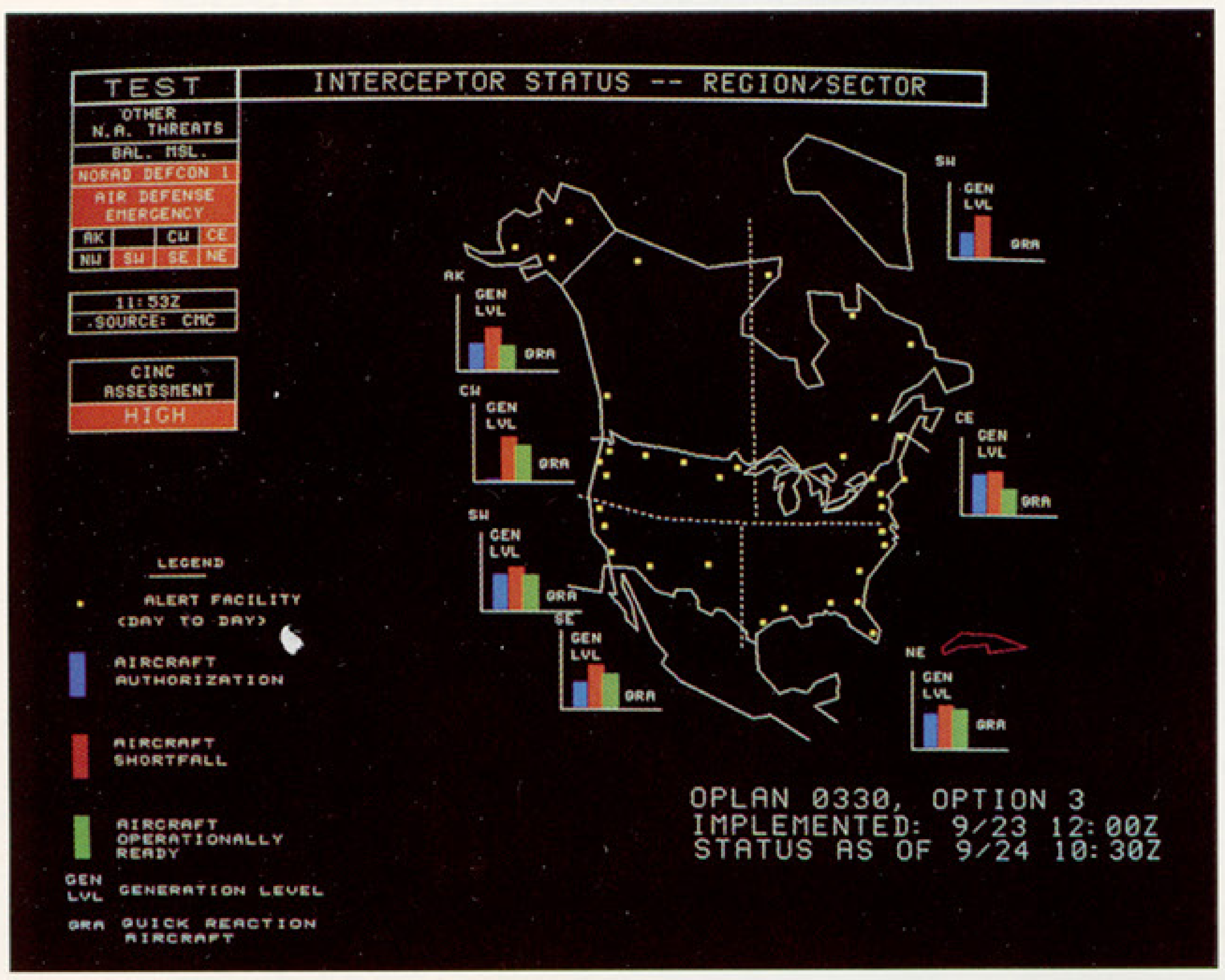

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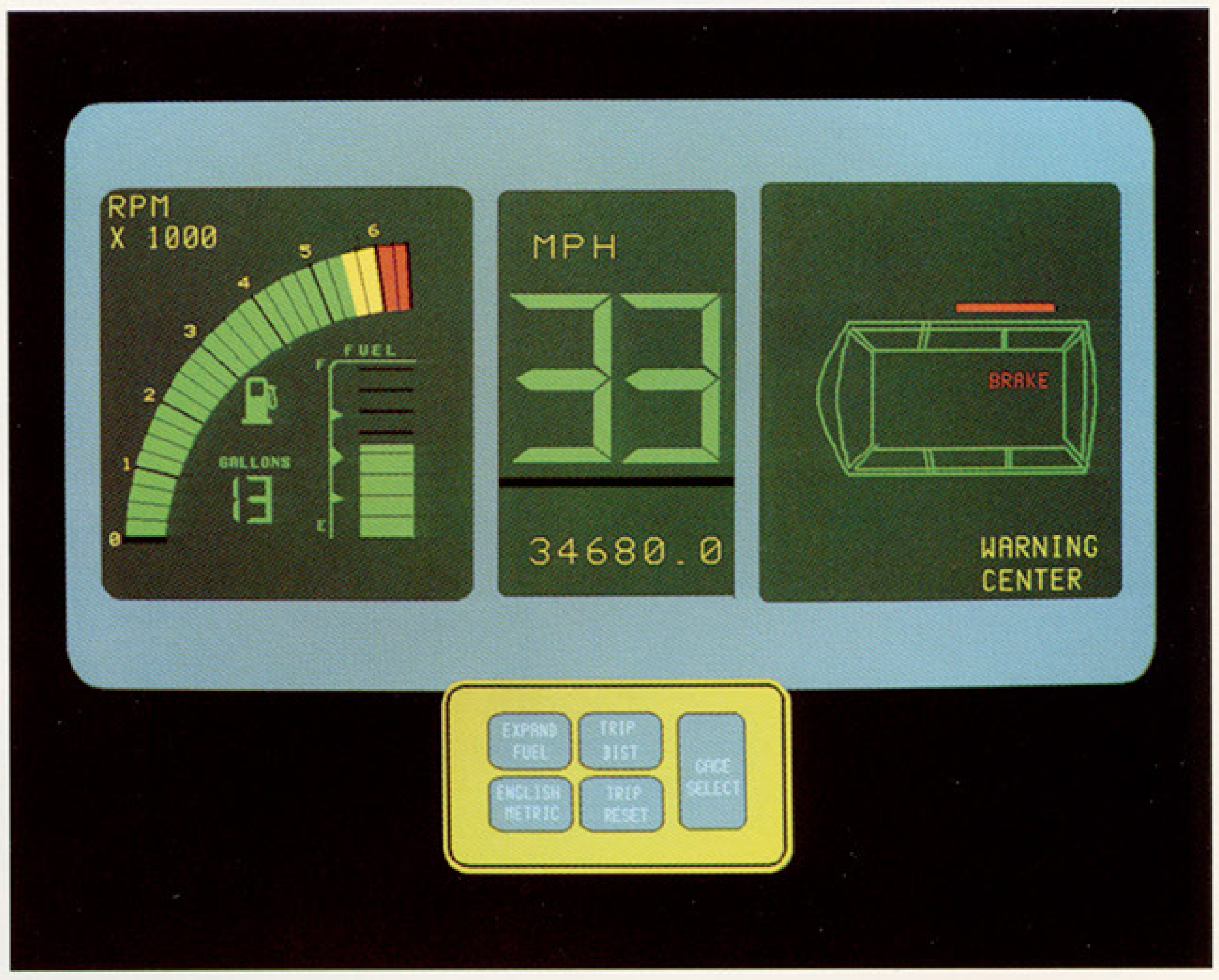

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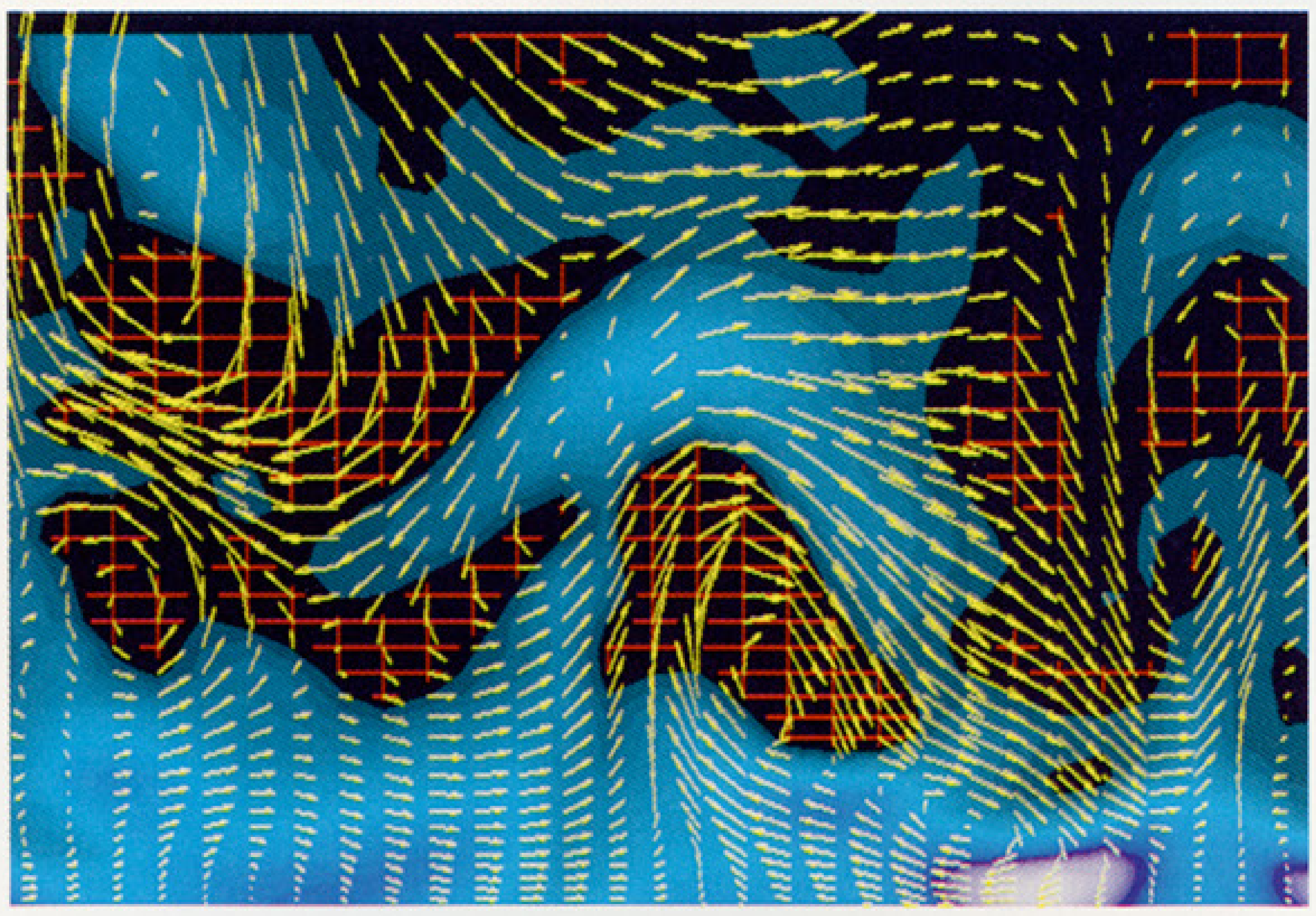
TURBULENCE IN THREE DIMENSIONS

Using stereo imagery, NASA is gaining a better understanding of 3D data describing the dynamics of turbulence.

BY STEPHEN K. ROBINSON

The application of supercomputer technology to aerodynamic design has created the field of computational fluid dynamics (CFD). Practitioners of the science simulate flows of a fluid (gas or liquid) over or through an aerodynamic body such as an aircraft, space shuttle, or rocket engine by solving the basic equations of fluid motion at thousands of points around the body. The end result is a large database of numbers corresponding to the velocities, pressures, densities, and temperatures within a given flow-field. Growing computational power has made it possible to successfully tackle increasingly complex aerodynamic problems, but this has led to a concomitant increase in the complexity of the numerical results.



The phenomenon of fluid turbulence, considered one of the last major unresolved issues in physics, certainly is one of the more complex problems, having limited the accuracy of many CFD applications to engineering design. Now, though, CFD methods are themselves being used to create turbulence computationally, with the results being scrutinized in much more detail than would be possible with the fleeting turbulence found in laboratory wind tunnels or over the wings of aircraft in flight.

Current supercomputers are capable of solving the equations of turbulent fluid motion at millions of grid points. But the resulting solution datasets are truly massive, especially for the time-accurate direct Navier-Stokes (DNS) simulations of turbulent flow-fields For example, Phillipe Spalart at NASA Ames Research Center has computed a DNS simulation of a turbulent boundary layer on a grid with 9.4 million nodes [Spal88]. At each time-step of the solution, seven 64-bit words representing the instantaneous velocity, vorticity, and pressure fields are stored at each node of the computational grid. For the 104 time-steps saved on tape, Spalart's boundary layer comprises 54.7 GB of information.

Gaining a physical understanding of turbulence phenomena from CFD datasets of this magnitude has become a research topic in itself. The challenge is to extract only that information needed for understanding, and to then display this data in some form which, while capable of conveying the essential physics, is less complex than the turbulence itself. The problem is truly multi-dimensional in that every flow variable is a strong function of position in three-dimensional space and time.

The visual display of CFD solutions

currently is the most effective and efficient method of transferring complex information from computational results to the scientist. Where numerical turbulence is concerned, the requirement for visual display is especially pronounced. However, the fact that graphics workstations are limited to projecting 3D objects on 2D monitors has historically limited our ability to understand highly complicated flow structures.

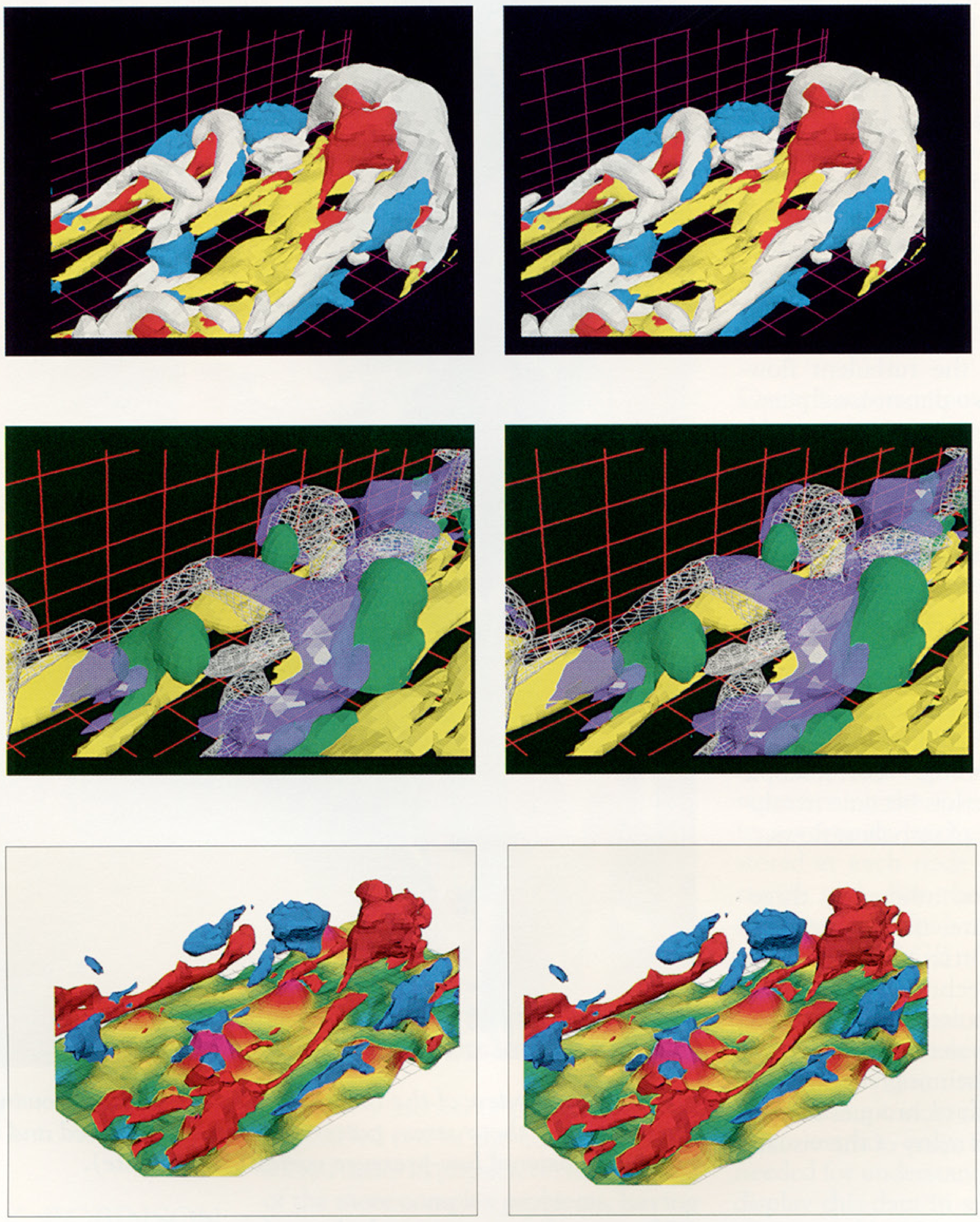
Complex details are apparent in any random slice of the turbulent flowfield. However, two-dimensional planes provide insufficient information to allow for human comprehension of the three-dimensional turbulent motions. For example, in the 2D image accenting the title of this article, it's impossible to ascertain the extent of vortex motions and their associated high-shear (blue) regions normal to the viewing plane. Some way of displaying the full three-dimensional character of turbulence is required to allow for a true understanding. Stereoscopic technology hence has become invaluable in the study of turbulent flows.

With its complex, inherently three-dimensional nature, turbulence presents a rich opportunity for utilizing stereo viewing techniques. In fact, experience has shown that non-stereo viewing of a turbulent flow-field can often be overwhelmingly confusing inasmuch as stereo techniques are virtually required for many of the visualizations.

Figure 1: A topview of the turbulent boundary layer showing the streaky instantaneous shear stress patterns at the surface (red and blue) with three-dimensional low-pressure vortex cores (white).

In Figure 1, for example, we find an overhead view of the simulated boundary layer. Although visually interesting, this image conveys only limited information about the topology and spatial relationships between the highly three-dimensional low-pressure (white) structures. In contrast, a stereo pair depicting a section of the same data (Figure 2) clearly displays the nature of these structures in space.

Because analysis in three dimensions is essential for understanding turbulence dynamics, a study [RobKlin89] is presently under way at NASA Ames to create stereo images and animations of numerically simulated turbulence. The results already have provided significant insight into previously unresolved issues of fluid physics. Using this new knowledge, improved mathematical models of turbulence are expected to be generated. These then can be



The uppermost pair (Figure 2) shows contour surfaces of low pressure (white), low streamwise velocity (yellow), outward ejections of low-speed fluid (red), and wallward sweeps of high-speed fluid (lavender). A level down (Figure 3), we see a closeup of a low-pressure vortex (the white net) with high streamwise velocity (blue), low streamwise velocity (yellow), and high pressure (green). The bottom pair (Figure 4) depicts a carpet plot of wall pressure fluctuations, with ejections (red) and sweeps (blue).

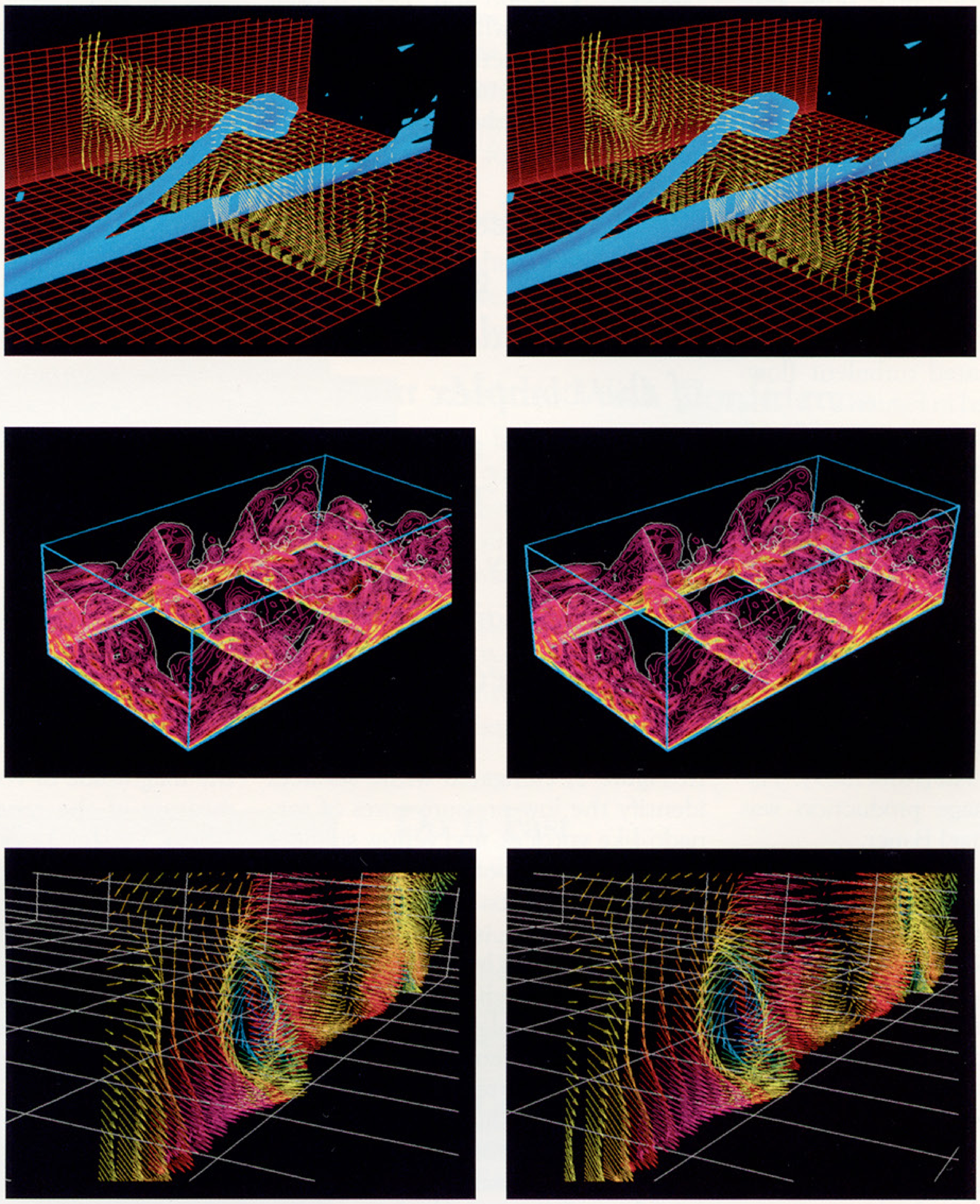


Figure 5, the top pair, shows a rear-wall shear layer (blue), with a streamwise vortex, indicated by cross-plane velocity vectors (yellow). The middle pair (Figure 6) illustrates total vorticity magnitude, with magenta representing low pressure, yellow representing medium pressure, and blue representing high pressure. The last pair (Figure 7) shows three-dimensional instantaneous velocity vectors, with blue representing low pressure and magenta representing high pressure.

utilized in CFD codes to more accurately predict friction drag, noise generation, and surface heat transfer for advanced aerospace vehicle designs such as supersonic vertical take-off aircraft, the hypersonic Aerospace Plane, and fuel-efficient unducted airline fan propulsion systems.

Turbulence Results

Examples of how stereo rendering techniques have been applied to the analysis of simulated turbulent flowfields are presented in Figures 2-7. The numerical database was generated with a direct Navier Stokes (DNS) simulation of a zero pressure-gradient, flat-plate turbulent boundary layer, computed by Spalart [Spal88]. The images were created on an IRIS 3030 workstation, with software written at Ames by Fergus Merritt, Gordon Bancroft, Pieter Buning, and the author. The stereo algorithms were coded by Ken Hu, and are explained in some detail by Robinson and Hu [RobHu89]. Assistance with image production was provided by Michael Bauer.

In the figures, iso-contour surfaces representing constant values of various turbulence quantities are shown as shaded surfaces, colored according to contour value or type of quantity. Results are rendered in a sub-volume of the computational domain. The floor of the sub-volume is just above the wall on which the boundary layer grows, and the sub-volume spans 83 percent of the mean boundary layer thickness.

In Figures 2 and 3, red, blue, and lavender regions show where significant contributions to turbulence production are occurring. The red surfaces identify regions of low-speed fluid moving outward, away from the wall in "ejections," and blue/lavender surfaces show where high-speed fluid is moving wallward in "sweeps." Ejection and sweep regions are the locations where the majority of turbulence production occurs and so are of major importance to the study of boundary layer turbulence physics.

NASA researchers now are gaining a deeper understanding of the complex motions that make turbulence what it is. This should eventually pay off in improved aircraft and spacecraft.

In Figure 2, elongated white surfaces identify the low-pressure cores of tornado-like vortices, and yellow surfaces enclose regions of fluid with low streamwise velocity. Near the wall, the low-speed fluid is elongated into streak-like regions by the intense near-wall velocity gradient. The stereo images clearly display the strong spatial association between the white vortex structures and the red and blue regions of turbulence production (sweeps and ejections). The complex topology of the different contour surfaces and their spatial association is made non-ambiguous through the use of stereo images.

A closeup of the turbulence data is shown in Figure 3, where lavender surfaces represent regions of high-speed flow, green surfaces enclose high-pressure volumes, white "netting" represents a low-pressure vortex core, and yellow marks the low-speed regions. The use of transparency and polygon edge rendering in stereo allows for rapid comprehension of the complicated spatial relationships between the regions.

Figure 4 shows a "carpet plot" of the instantaneous wall pressure at the floor of the computational domain. In this technique, both the color and height of the surface correspond to the local value of the wall pressure. High pressure regions are represented by magenta peaks and low pressure regions are shown as blue valleys. Green plains are nearly equal to the mean wall pressure. Ejection (red) and sweep (blue) contour surfaces are also included in the figure to illuminate the relationship between wall pressure fluctuations and the near-wall turbulence generation events.

Two cross-planes through the simulated boundary layer are shown in Figure 5. The blue contours correspond to the magnitude of vorticity, which is a measure of the tendency for fluid to "shear," or slide over itself. This shearing motion extracts energy from the faster flow away from the surface and helps to produce more turbulence. The yellow velocity vectors show a vortex just beneath the blue "shear layer." The co-existence of these two flow features suggests a cause for the formation of the internal shear layers, which are known to play a major role in the near-wall dynamics.

Figure 6 shows data plotted only on the planar edges of a sub-volume of the computational domain. The lines are contours of total vorticity magnitude that give a local measure of the intensity of the turbulent motions. High values of vorticity are blue, medium values are yellow, and low values are magenta. (This somewhat non-stan-

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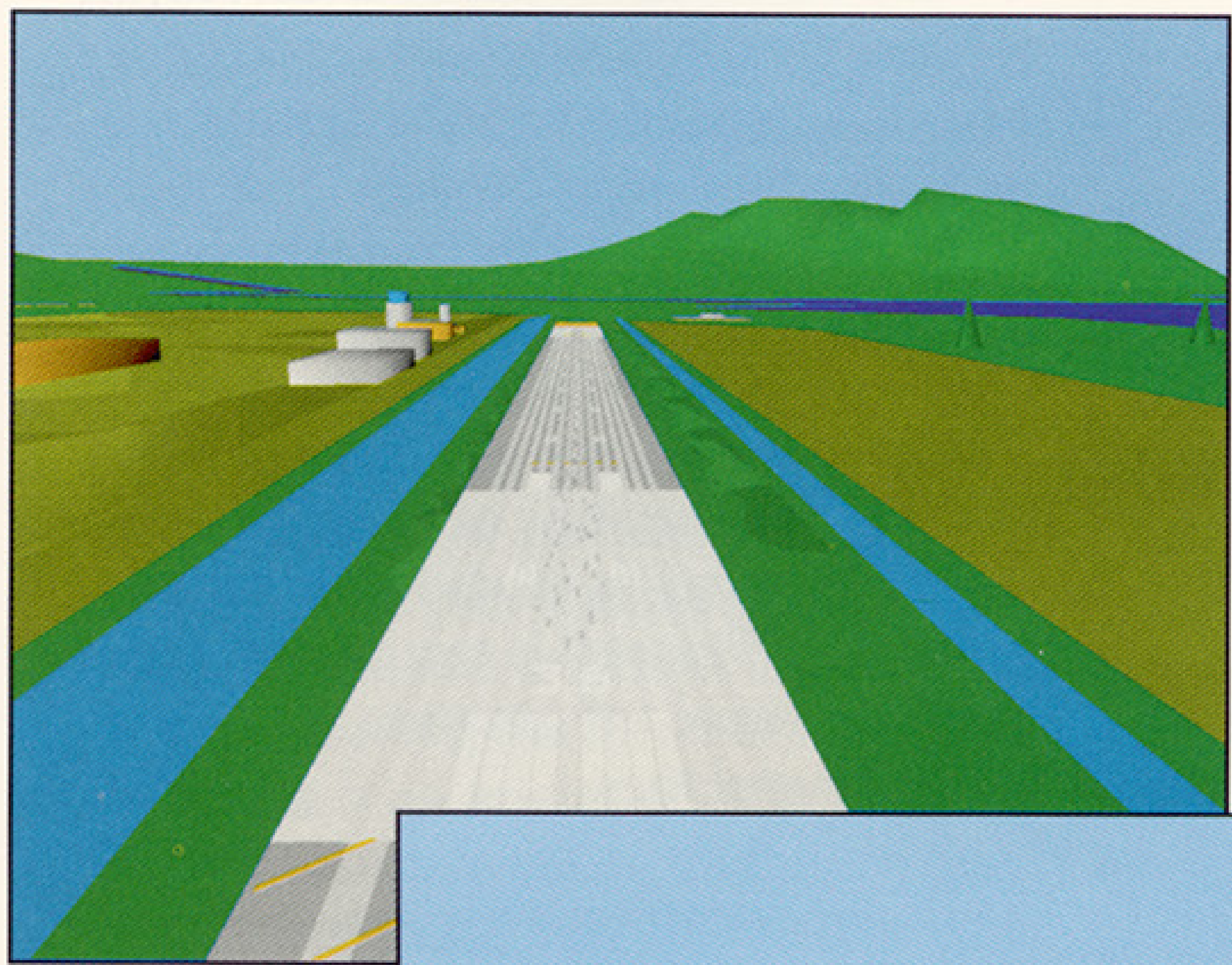

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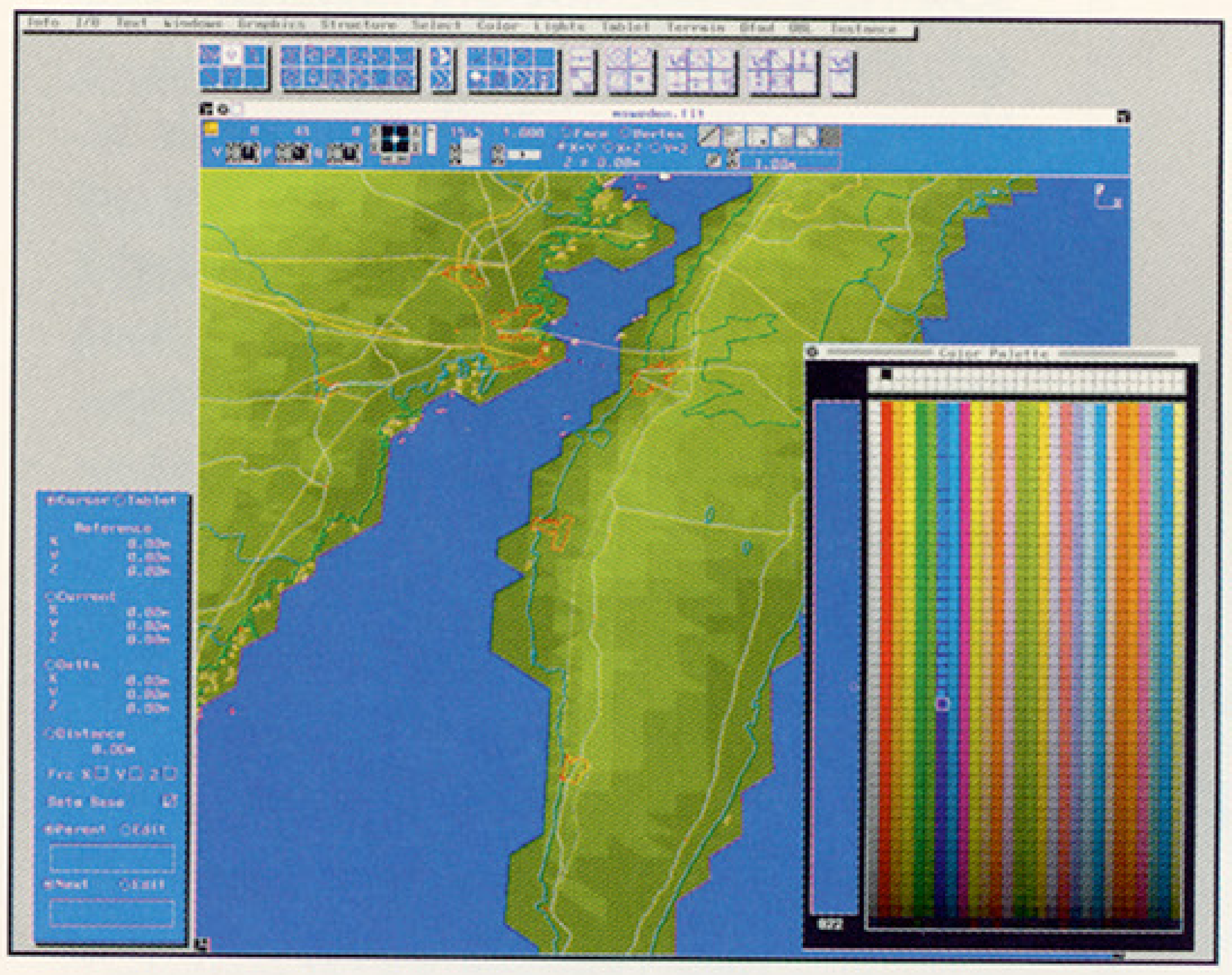

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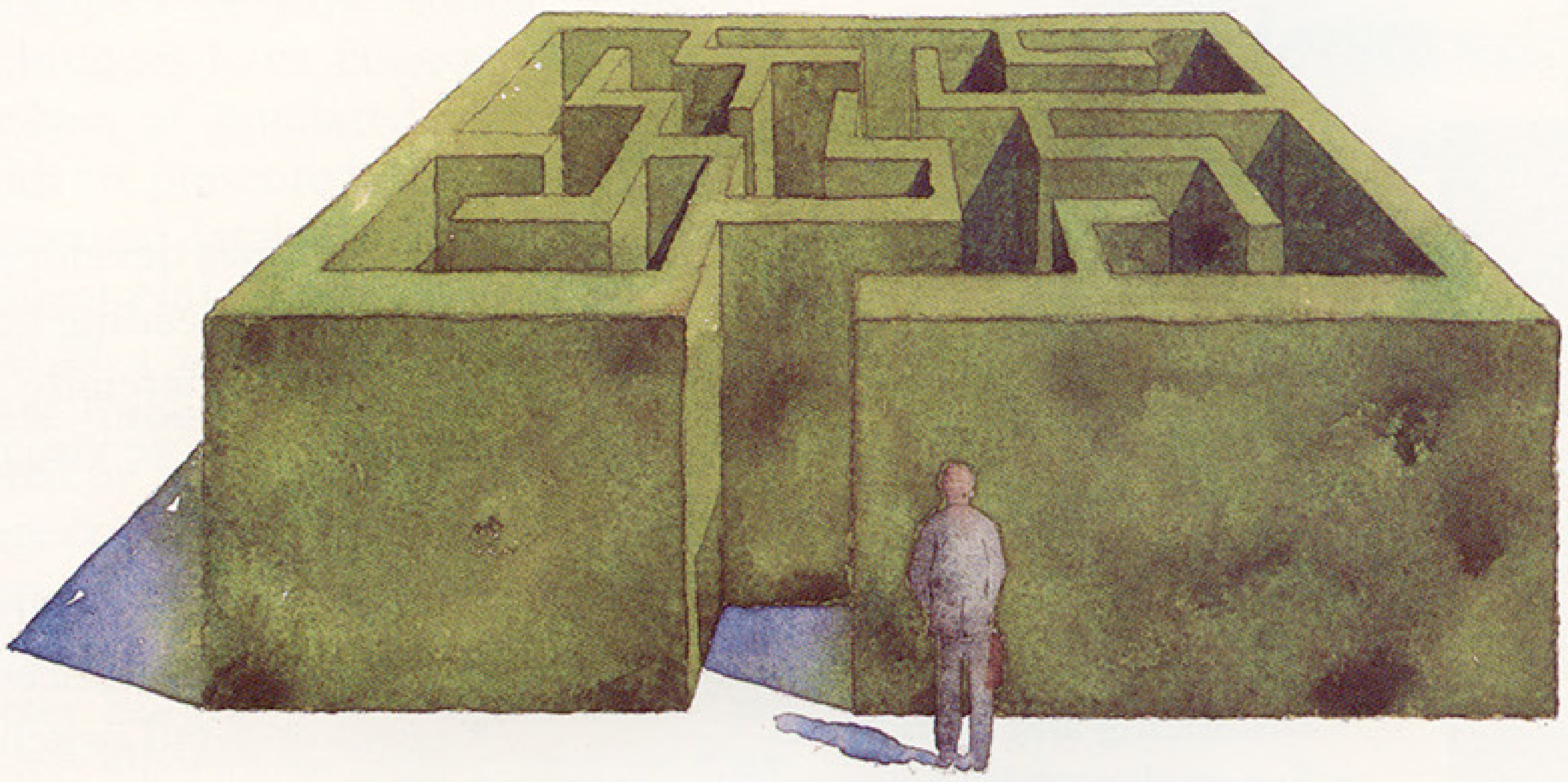


dard color map was chosen to accentuate the outer edge of the boundary layer, where the total vorticity approaches zero.) Large bulges in the instantaneous interface between the turbulent boundary layer and the outer non-turbulent flow are visible in both the streamwise and cross-stream planes. Near the wall, small-scale shear layers are visible as regions of green and yellow protruding from the wall. Stereo viewing of Figure 6 is required to separate the visual information from each of the four planes.

Turbulence cannot exist in two dimensions, so viewing the instantaneous three-dimensional velocity field provides a way for sampling the essence of turbulence. As Figure 7 demonstrates, this is greatly facilitated through the use of stereo imagery. Here, the 3D velocity vectors are shown for a cross-plane in the boundary layer, through which a streamwise vortex passes. The vectors are colored according to the local pressure field, with blue representing low pressure and magenta signifying high. The low-pressure core of the swirling vortex is clearly visible in the picture. This simultaneous display of four quantities in the flow-field (three components of velocity and pressure) to detect internal flow structures is a good example of the advantage computer graphics offers for the study of numerical turbulence.

Figures 2-6 are frames taken from a series of 16mm stereo animations generated using the numerically simulated boundary layer database. Most of the animations involve time-evolving turbulence, since the kinematic relationships between the various regions of interest can be made relatively clear through the use of stereo. In each of these complex scenes, stereo viewing greatly enhances comprehension.

Summary

Given that virtually anything that travels through air or water is enveloped in a sheath of turbulence, the practical application of CFD to successful aerospace designs requires accuracy in turbulent fluid flow modeling. But because of our incomplete understanding of turbulence, state-of-the-art models are inaccurate for many flows of critical engineering importance, including the flows surrounding aircraft at high angles of attack, those found in aircraft wakes, and those that pass through engines. By using stereo imaging techniques with numerically-simulated turbulence, though, NASA researchers now are gaining a deeper understanding of the complex motions that make turbulence what it is. This new knowledge, combined with the results of 45 years of turbulence physics research, is paving the way to higher degrees of accuracy in CFD design codes. The eventual payoff likely will come in the form of quieter, safer, and more efficient aircraft, spacecraft, and automobiles. ■

Steve Robinson recently earned a PhD in Mechanical and Aerospace Engineering from Stanford. Since 1979, he has been employed as a research scientist in the Experimental Fluid Dynamics Branch of the NASA Ames Research Center, where he researches aerodynamics, turbulence physics, and biomechanics.

References

[RobHu89] S.K. Robinson, and K.C. Hu, *Stereo Image Visualization of Numerical Turbulence*, AIAA-89-0141 (1989).

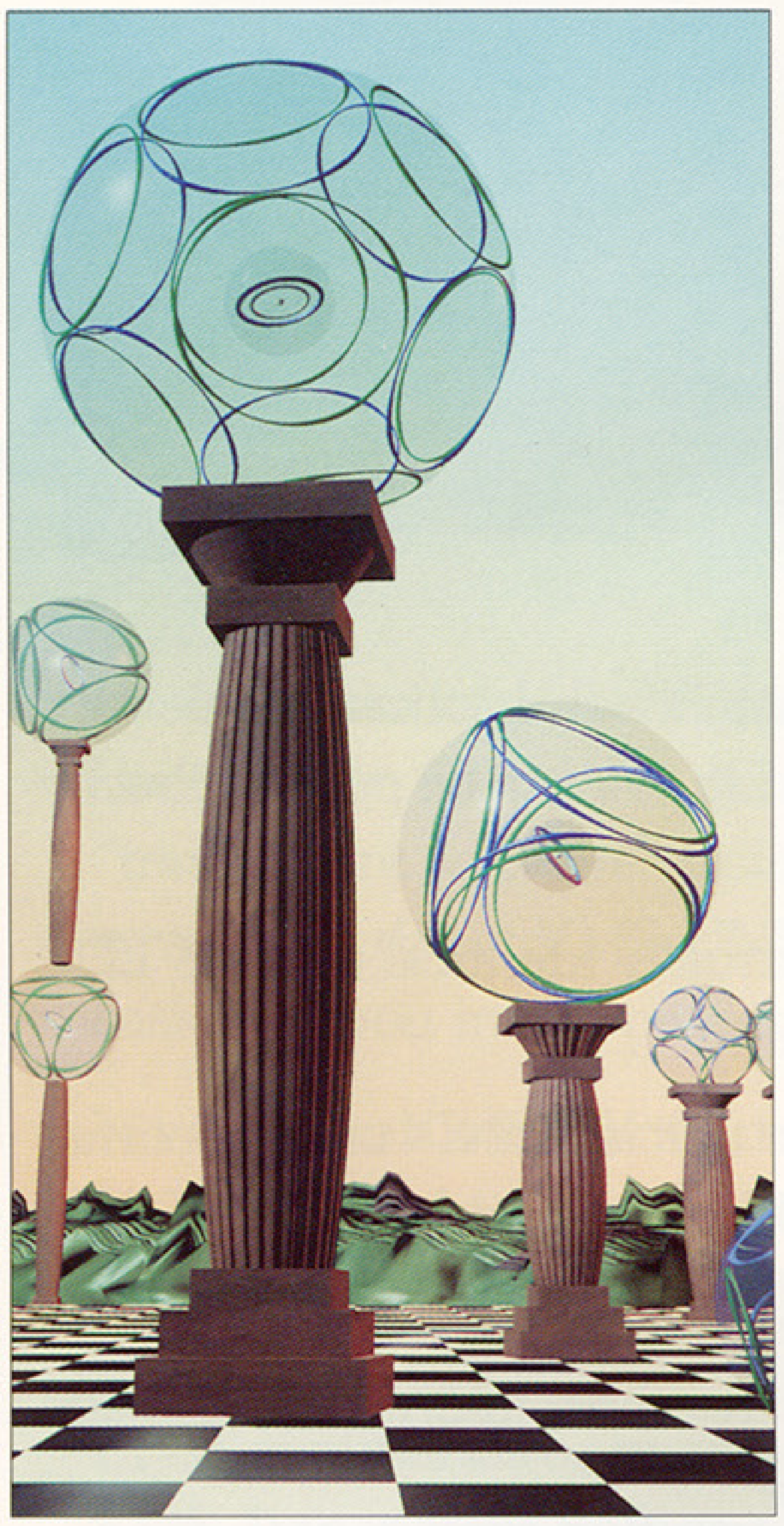
[RobKlin89] S.K. Robinson, S. J. Kline, and P.R. Spalart, *A Review of Quasi-Coherent Structures in a Numerically Simulated Turbulent Boundary Layer*, NASA TM-102191 (1989).

[Spal88] P.R. Spalart, "Direct Simulation of a Turbulent Boundary Layer up to $Re_\theta = 1410$," *J. Fluid Mech.*, Vol. 187, pp. 61 (1988).

PICTURE SHOW

Portrait of an Atom

By Kenneth Snelson



Discussions of computer-generated stereo imagery seem inevitably to focus on potential applications in the medical, scientific, or engineering arenas. But the role stereo can play in the arts is no less significant.

Sculptor/artist Kenneth Snelson, whose work has largely been fueled by the desire to better understand the physical and aesthetic rules governing spatial relationships, has long nurtured an interest in stereo imagery. Evidence of the impact stereo has had on his work can be seen in the accompanying pairs, drawn from the exhibit "The Nature of Structure" (presently on display at the California Museum of Science and Industry — through August 27 — and scheduled to appear at the National Academy of Sciences April 5 through June 25, 1990). An IRIS 3130 running Wavefront Technologies software was used to generate the images.

When questioned recently about how he first came to employ stereo technology for his work-in-progress, "Portrait of an Atom," Snelson responded:

Sometimes I'm asked if it isn't odd to switch from real materials — metal, wood, and plastic — to the bodiless medium of electrons and silicon chips. Perhaps the shift would be awkward were I trying to use the computer to achieve the same results possible with solid materials. But that isn't my goal.

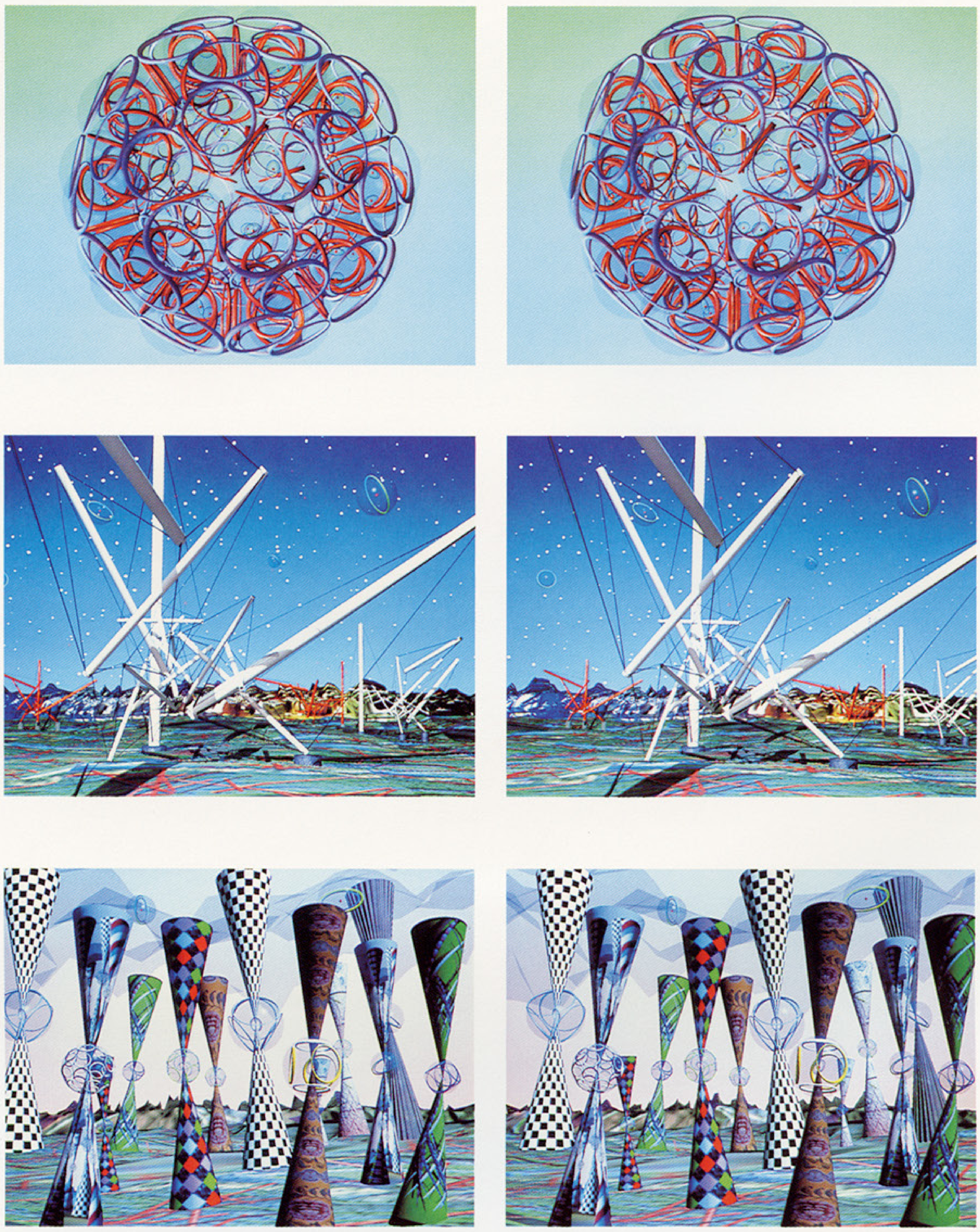
Mostly, I'm reaching for images that describe worlds which might be but aren't — and perhaps aren't even feasible. This ability to visualize the unseeable is what led me to use a 3D graphics computer in the first place.

Of course, it's important that I be able to actually *see* my synthetic scenes much as I am able to view objects in the physical world. To this end, I have long been fascinated with stereo photography, having studied its history and having experimented with a good many approaches over the years. Since purchasing my 3130, though, even I have been surprised to find how much of a difference stereo makes. My imagined objects, when viewed in stereo, become remarkably more convincing than when they're available only as flat images.

Mostly, I'm reaching for images that describe worlds that might be but aren't.

This is especially true of my imagined C_{60} form, the "buckyfullerene" molecule. Although purely theoretical, the structure can be made to appear astonishingly real, thanks largely to the quality of the rendering, but due as well to the power of stereo viewing. ■

Kenneth Snelson's sculptures and computer-generated images are represented in more than 40 public collections worldwide.



In the uppermost pair is a representation of an imagined C_{60} molecule. One level lower is a stereo presentation of the sculpture, "Forest Devil by MoonNight," shown here bathed in an eerie glow. Notice how the stereo presentation carries one back along the texture-mapped ground toward the stars. The lowest of the pairs shows "Loquacious Cones," mysterious hourglass objects scaled ambiguously and made to stand awry. Although apparently constructed as enormous objects on an expansive landscape, they seem more like a table-top still-life because of the exaggeration in their stereo eye separation (hyper-stereo).

VENDOR FORUM

Turn Up the Stereo On Your Volume

By N. Blair Butterfield

Although stereo viewing is relatively new to many fields, the technology already has become quite well established in the biological sciences. Researchers in electron microscopy, in fact, routinely create stereo pairs. In neurobiology, meanwhile, work is being done to pioneer the application of stereo viewing to volume rendering.

In keeping with this trend, Vital Images Inc. recently added stereo viewing to its volume rendering package, VoxelView. Designed originally to render volumes obtained through laser-scan confocal microscopy, VoxelView can also handle data sets from medical and industrial CT scans, magnetic resonance scans, computational fluid dynamics, theoretical chemistry, seismological surveys, and astrophysics. In each of these areas, stereo viewing makes data volumes more intuitively understandable.

The confocal microscopy research upon which VoxelView is based comes from Maharishi International University in Fairfield, IA, where it has been supported by grants from the National Science Foundation and the Iowa Department of Economic Development.

A confocal microscope acquires an image by scanning a specimen object with a laser, point by point. The specimen typically contains a fluorescent dye, distributed unequally throughout the volume. Upon laser illumination, the light emitted from each point in the object is digitized and recorded together with the *xy* coordinates of that point. By stepping the focus plane vertically through the specimen, a series of very thin (0.0005 mm), high-resolution, 2D optical slices of the volume can be obtained. In several respects, the data acquired in this way on the microscopic level is very similar to that obtained from a CT scan of an entire human body.

The challenge is to render the 3D microscopic volume data using 3D computer graphics technology. Of the two rendering approaches available — geometric rendering and volume rendering — Dr. Vincent Argiro, founder of Vital Images, chose the latter for several important reasons.

In geometric rendering, primitive two-dimensional shapes (lines or polygons) are joined together in a meshwork to approximate the surfaces of three-dimensional objects. Typically, the user (or some surface-detection and segmentation algorithm acting on behalf of the user) must first decide how to distinguish the different surfaces composing an object. The user must also determine how to construct these surfaces from geometric primitives. Since most human eyes have never before seen the highly irregular objects visualized with a confocal microscope, the selection of geometric primitives for rendering such data sets is not intuitively obvious. Accordingly, a geometric rendering approach was rejected by the Maharishi researchers as being susceptible to artifacts and misinterpretation.

Volume rendering, on the other hand, conceptually divides a 3D volume into tiny cubes, identifying their locations in the continuous volume with *x*, *y*, and *z* coordinates. Each of the cubes, called "voxels" (or "volume elements"), has an associated value that quantifies some property of the object, such as its density or luminosity.

Thus, a graphical reconstruction of the original object becomes a process of stacking voxels as indicated by the associated location data. Volume rendering algorithms organize this stacking procedure based on the changing viewpoint of the observer — by performing coordinate transformations. Concurrently, they determine *how* to display the information represented by each voxel by referring to certain coloring, transparency, and shading calculations.

Vital Images chose SGI's superworkstations as a vehicle for VoxelView because the entire SGI architecture is ideally suited for maximizing interactivity. By collaborating with Silicon Graphics' engineering team, the scientists developing VoxelView have been able to achieve volume rendering performance measures that lead the industry. On recent tests, a benchmark of 1.1 million voxels per second was recorded on the IRIS 4D/220GTX. Speed like this makes it possible to regenerate images on the screen in just a second or two — or

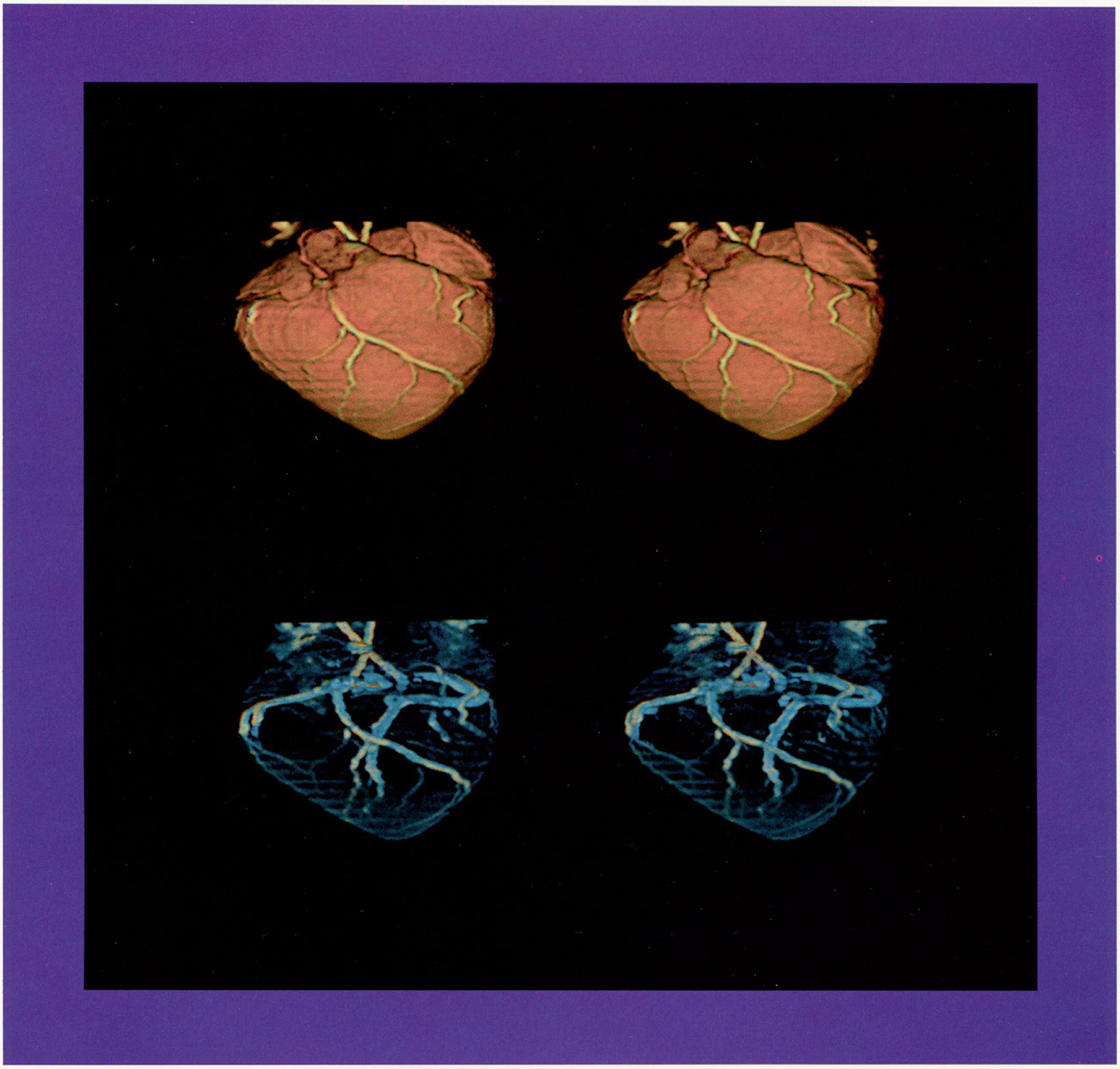


Figure 1: In this medical imaging example, we see a living heart captured in 3D by the Ciné CT scanner manufactured by Imatron. The uppermost image offers an exterior view colored anatomically and illuminated using an imaginary light source. The lower of the two images was rendered to reveal the three-dimensional shape of the arterial tree inside the heart. This volume rendering approach, currently under development, may soon serve as a rapid method for diagnosing heart disease. [Data and renderings courtesy of Boyd Knosp, Mel Marcus, Rob Weiss, and Randy Frank, University of Iowa Image Analysis Facility.]

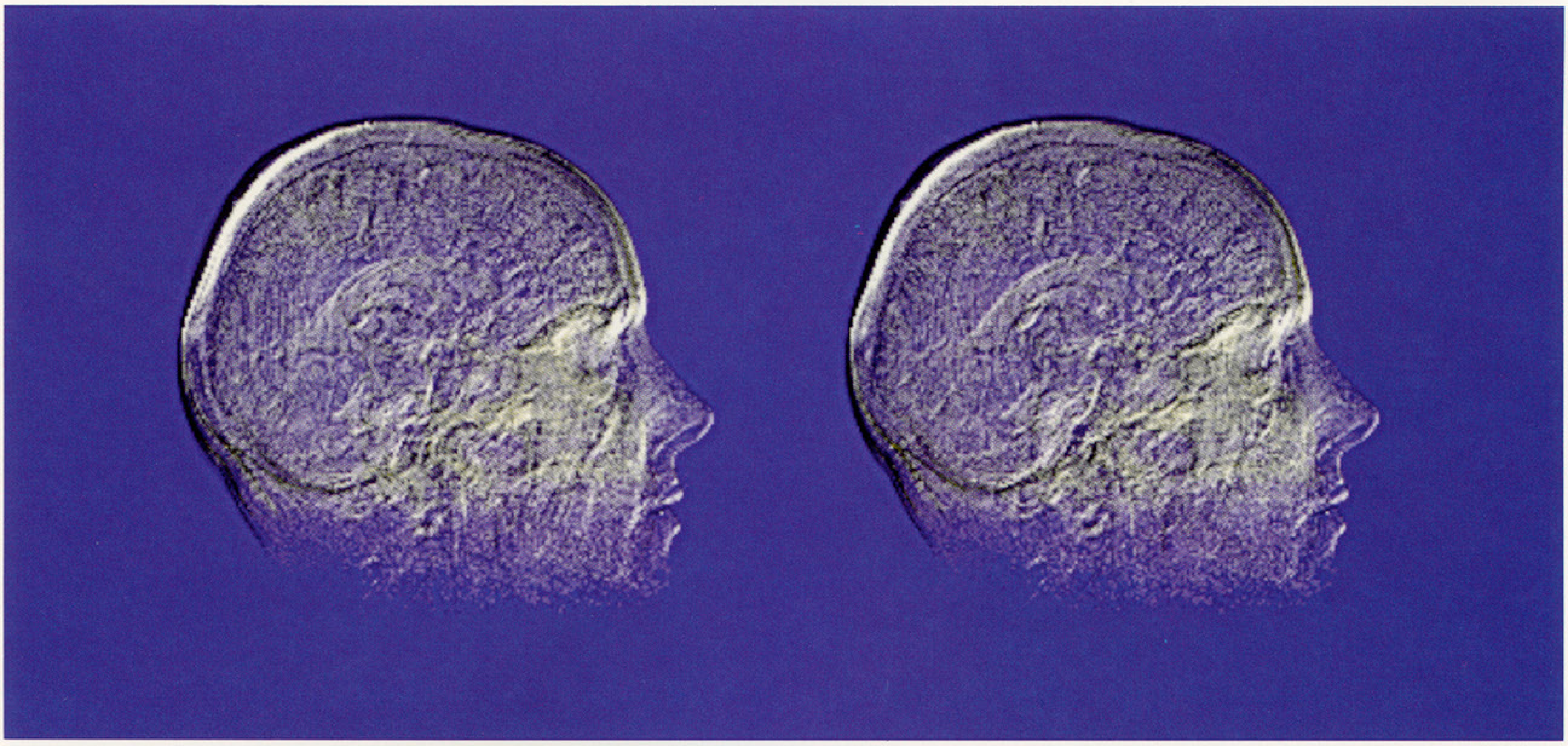


Figure 2: The Magnetic Resonance Imaging (MRI) volume rendering shown here of a human head was made almost transparent in order to reveal certain internal structures, specifically the ventricals and folds of cerebral cortical surface. Note the dual profiles of the skull and skin along the chin and nose, as well as the fine structure of the brain stem deep within the head and neck. The hardware lighting model and gradient thresholding have been applied to accentuate surfaces and subtle tissue boundaries.

even less for some data sets. It is thus possible to rotate, color, section, and adjust a given volume's transparency, lighting, and other features in real time. Also, VoxelView has added an option for creating on-screen animation sequences. Interactive features of this sort allow users to derive far more information from a volume data set than would otherwise be possible.

To increase the intuitive accessibility of renderings, moreover, the ability to view objects in stereo has been added. The improvement is especially noticeable when a volume rendering depicts "fuzzy" and translucent objects, such as molecular orbitals or soft tissue. Indeed, a stereo view may provide the *only* meaningful depth perception cues possible for such objects.

Dr. Steven Senft, a research fellow at the McDonnell Center for Studies of Higher Brain Function at Washington University in St. Louis, has worked with VoxelView's stereo viewing option as part of his work with nerve cells. Regarding the benefits, he says, "Stereo viewing provides greater visual acuity, and thus gives a more dramatic appreciation for the volume. This is particularly true when the stereo images are rendered dynamically, since the element of movement gives the viewer something to lock onto, and that something has the additional advantage of providing a built-in depth cue. Essentially, stereo viewing is a very simple, elegant technique that significantly enhances the visual impact of a rendered volume."

Adds William Van Zandt, director of research and development at Vital Images, "What appeals to me most about viewing rendered volumes in stereo is that it creates the same experience one would have when viewing an object through a stereo microscope. Once the visual system adapts, you feel so close to the object that you can get totally absorbed in it — as if the object were an extension of your own consciousness." ■

Blair Butterfield manages user documentation development for Vital Images, Inc.

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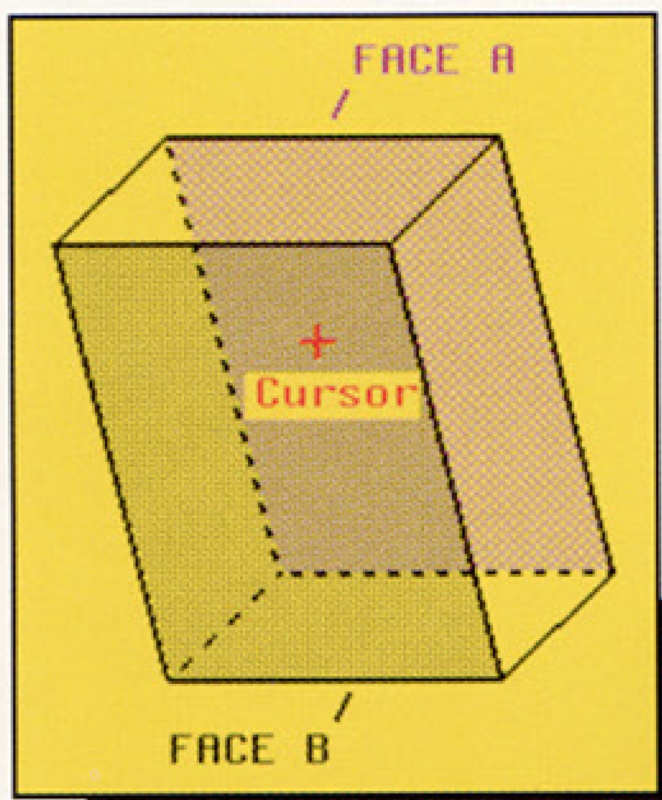
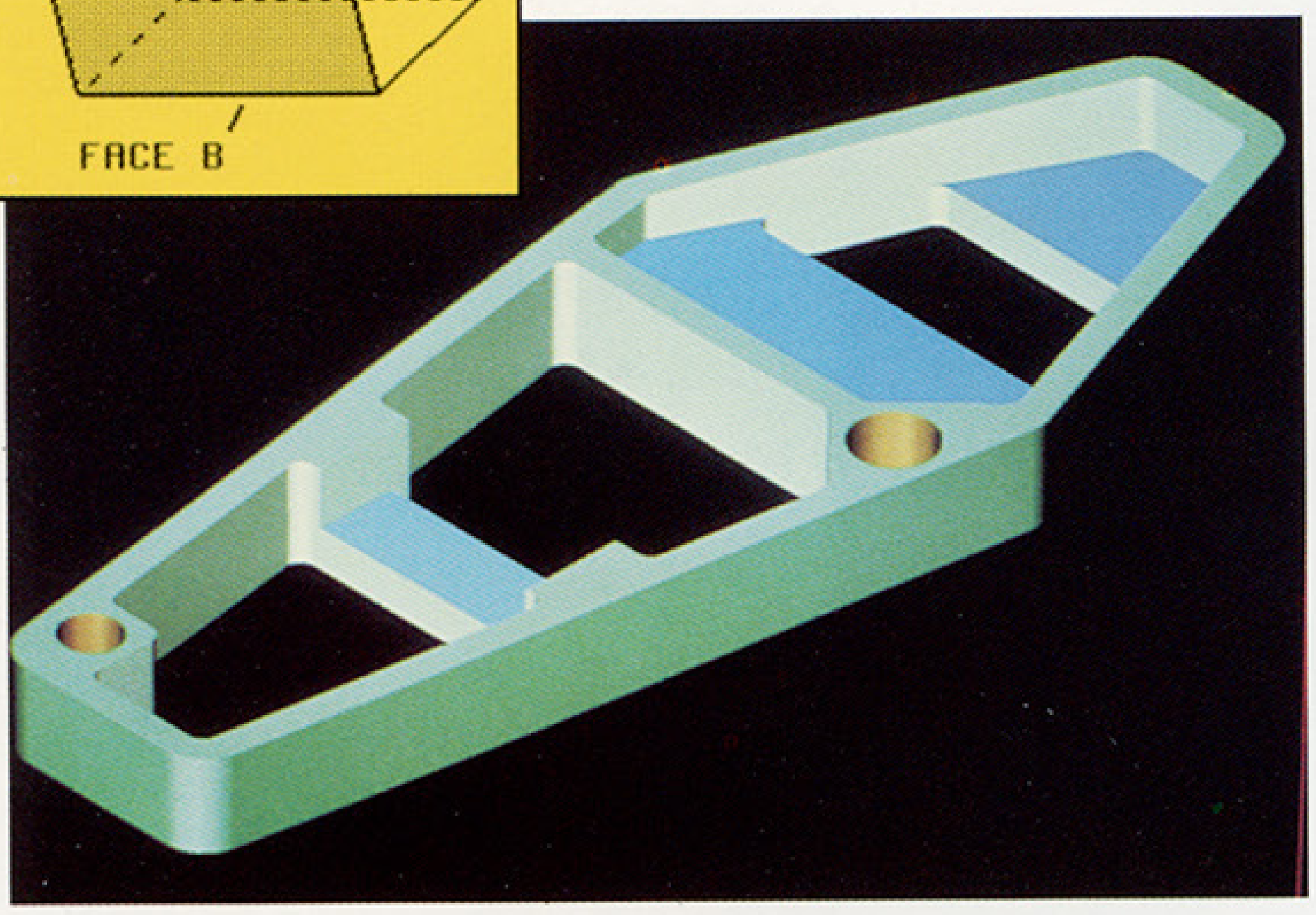
PROGRAMMER'S CORNER

Picking From the Picked Few

By Yusuf Attarwala and Marvin Kong





Typically, at least a few of the surfaces of a 3D rendered object will be hidden when the object is viewed from particular angles. At these orientations, users employing hardware picking techniques to select one of the visible surfaces (or polygons) are bound to get more than one hit. And since the order of polygons in the pick buffer is governed by the order in which they were drawn, one cannot be sure of which surface is in front. The two-step technique described below, however, allows you to pick the visible surface (assuming you have a *z*-buffer).

1) Perform the usual hardware picking ritual and examine the contents of the pick buffer. If the number of hits equals one – BINGO – you're home free. If the number is greater than one, go to step 2.
2) Set up a color-lookup table. Paint all of the polygons picked in step 1 in the backbuffer with *z*-buffer on. Each polygon should be painted a unique color. Perform a **readpixel** (or **readRGB**) operation in the backbuffer at the cursor location. Match the color information returned by **readpixel** with the color-lookup table to identify the polygon to be picked.

If the number of unique colors in step 2 is less than the number of picked polygons, you'll need to loop through the color table, repeating step 2 when more than one polygon is selected with the same color.

The segment of code shown on the facing page should provide a feeling for the suggested technique.

Case Study

To see how this picking approach might be applied, consider the simple line drawing to the left. Although face (or polygon) A is hidden partially behind face B, it's possible it was rendered prior to face B. Thus, when picking, the user will get two hits if the cursor is at the location indicated.

In the pick buffer, the entry for face A will appear before that of face B. Even if we rotate the object to place face A in front and then perform picking, the pick buffer will remain unchanged. Hence, by relying only on the pick buffer in step 1, we may get the wrong results. This problem will become more acute as the object or scene grows more complex, as illustrated by the bracket shown adjacent to the line drawing (image courtesy of Automation Technology Products).

Happily, a fast, reliable solution is available by combining the hardware and software techniques discussed here. ■

Yusuf Attarwala and Marvin Kong are members of the technical staff working in SGI's Application Products Division.

```
#include  <gl.h>
#include  <device.h>

RGBvalue   red[100],  green[100],blue[100];
RGBvalue   r[100],    g[100],    b[100];
int   pick_index[100][100][100];

main  (argc,argv)
{
  initialize();
  draw_scene();
  pick_a_poly();
}

initialize  ()
{
  int i;

  /* Open windows, set up menus, queue  */
  /* devices, etc.                      */

  /* Set up the color-lookup table      */
  /* (don't use black since this is the */
  /* background color).                 */
  if in rgb mode {
    for (i=1; i<=100; i++) pick_index[i]
    [i][i]= i;
  } else if in colormap mode {
    /* Use colormap mode if using a     */
    /* Personal IRIS.                   */
  }
}

draw_scene()
{
  for each polygon in the object {
    polf(....);
  }
}

pick_a_poly()
{
  short i;
  short  buffer[100];
  int num_hits, num_names = 100;

  /* — STEP 1 — */

  initnames();
  pick(buffer,num_names);
  for each polygon in the object {
    pushname(i); /* loadname if desired*/
    polf(....);  /* render the polygon */
    popname();
    i++;
  }
  num_hits  =  endpick(buffer);

  if (num_hits > 1) {

    /* — STEP 2 — */

    /* Make sure that double buffer and */
    /* z-buffer are on.                 */
    backbuffer(TRUE);
    zbuffer(TRUE);

    /* Clear background to black.       */
    if in rgb mode
      RGBcolor(0,0,0);

    else if in colormap mode
      color(BLACK);
    clear();

    /* Render each picked polygon in a  */
    /* unique color.                    */
    i = 1;
    for each polygon in the pick buffer {
      if in rgb mode
        RGBcolor(red[i],green[i],
        blue[i]);
      else if in colormap mode
        color(i+63);
      polf(. . . .);
      i++;
    }

    /* Get the pixel color at the       */
    /* cursor location and identify     */
    /* the picked poly (pick_poly is    */
    /* the polygon color-map index).    */
    if in rgb mode {
      readRGB(1,r,g,b);
      picked_poly  =  pick_index  [r[0]]
      [g[0]][b[0]];
    } else if in colormap mode {
      readpixels(1,col);
      picked_poly  =  col[0]-63;
    }
  }
  else if (num_hits == 1)  {
    picked_poly is in the pick buffer;
  }
}
```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NEW PRODUCTS

Entry Systems Graphics Enhancements

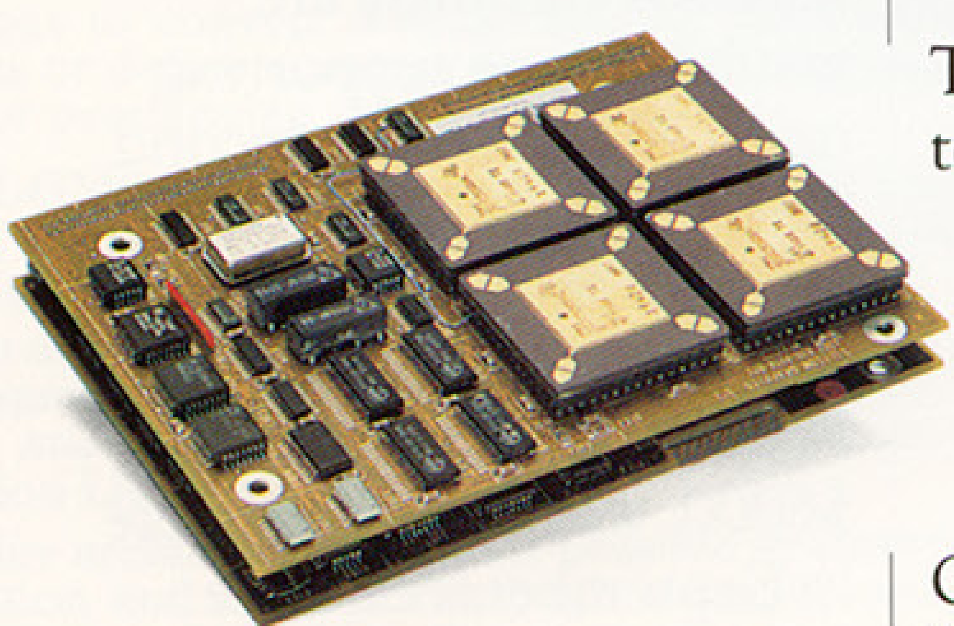
Silicon Graphics has announced a Turbo Graphics add-on board and an enhanced Geometry Engine for its Personal IRIS series of workstations.

The add-on board, fully compatible with the current IRIS Graphics Library, has been designed to slot into existing Personal IRIS systems. The boost in graphics performance thus afforded is more than two-fold.

Once configured with the board, a Personal IRIS will deliver more than double its former 3D vector rate, and triple its original 2D vector speed.

The new 14-inch monitor option for the Personal IRIS.

Turbo Graphics allows 200,000 3D vectors to be drawn per second. The 3D polygon rate per second has been benchmarked at upwards of 20,000. When sold as a factory-installed option, the add-on board costs $7000.



The Graphics Turbo upgrade for the 4D/20.

Silicon Graphics has also announced that all future Personal IRIS systems will be shipped with an upgraded Geometry Engine chip.

The new graphics subsystem provides improved anti-aliasing, pixel unpacking, raster operations, and hardware-based screen-masking.

Call your local Silicon Graphics sales representative to obtain more detailed information.

Personal IRIS Price/Performance Improvements

The Mips R3000 chip has been integrated into the Personal IRIS, giving the machine 16 MIPS of computational horsepower — a 60 percent gain over the previous generation of R2000-powered 4D/20 systems. Full binary compatibility has been maintained.

Running at 20 MHz, the R3000 delivers 1.4 MFlops. A large cache (32/64 Kbytes) makes this performance possible.

When sold as a factory-installed option, the R3000 board costs $4000. Starting in October, the option will be made available to existing Personal IRIS customers.

New manufacturing efficiencies and the addition of some configuration options, meanwhile, have made it possible for Silicon Graphics to reduce the price of complete Personal IRIS systems by as much as 35 percent. A 24-bitplane, 24-bit z-buffer system, for instance — formerly available for $35,000 — now costs just $25,500.

A new option that offers particularly significant savings is a 14-inch 1024x768 monitor, shown to the left. To get more detailed information, call your Silicon Graphics sales representative.

Kuck & Associates Numerical Libraries

Kuck & Associates' tuned numerical libraries, CLASSpack and SIGpack, are now available on the IRIS 4D Power Series.

The KAI Numerical Libraries are a set of high-performance algorithms designed to optimally manage the hierarchical memory and parallel capability of the Power

Series' multiprocessor architecture. Among the applications where these algorithms can be used to best effect are finite element analysis, computational fluid dynamics, computational chemistry, seismic exploration, tomography, and structural analysis.

The CLASSpack library contains dense linear system solvers and eigensystem solvers that are compatible with LINPACK and EISPACK. It also contains a complete package of iterative sparse matrix solvers, and comes with specialized algorithms for computational fluid dynamics and other disciplines.

The SIGpack Library contains signal processing routines aimed at applications in the fields of seismic exploration, radar and sonar processing, radio astronomy, and tomography. All of these routines are compatible with the proposed Seismic Subroutine Standard Library.

Kuck and Assoicates, Inc., based in Champaign IL, is best known for its pioneering work in matrix-matrix basic linear algebra subroutines (BLAS3), executed at the University of Illinois' Center for Supercomputing Research and Development (CSRD).

Available in August, the CLASSpack and SIGpack libraries are priced at $5000.

Graftel Ethernet Color Hardcopy Manager

The EM100 Ethernet Color Hardcopy Manager, recently announced by Graftel Systems, Inc. (Wilmington, MA), makes it possible for Silicon Graphics workstations to be connected to color hardcopy devices over Ethernet. The system combines hardware and software to convert color printers and film recorders into shared network resources.

Firmware drivers in the product support thermal transfer color printers, ink-jet color printers, and digital film recorders. The user interface consists of pop-up menus for controlling screen printing, file printing, printer selection, colors, and format. Any portion of the screen or any stored graphics file can be selected and printed using color that's resolution-independent of screen limits.

Among the color controls offered by the EM100 are a full 24-bit color data path, and support for 16 million colors, gamma correction, and variable pixel dithering patterns.

The hardcopy manager drives one thermal or ink-jet printer through a high-speed Centronics interface and one DC100 Digital Film Recorder through an RS232 port. Support for a second printer can be added.

The complete system, including a 10-user software license, sells for $5995. Availability is 15 days ARO.

Live Color Video Digitizer

Silicon Graphics has announced a Live Color Video Digitizer (LVD) option for its Power Series of workstations. A plug-in board capable of working with either VCR or video camera inputs, the LVD makes it possible to mix live color video images (operating at 30 frames per second) with high-resolution, real-time 3D graphics. The integration of graphics and video is complete enough to allow for the use of standard graphics operations on live video imagery.

Among the features of the LVD are:

- support for up to 30 frames per second.
- Support for RGB and composite video at NTSC and PAL resolutions.
- programmable sampling rates from 10 to 20 MHz.
- ten software-selectable RGB anti-aliasing filters.
- input lookup tables (LUTS) for color mapping.
- full integration with SGI's 4Sight window manager.

The LVD consists of a video digitizer, three circulating video frame buffers, and a high-speed pixel bus interface.

The Power Series' pixel bus provides sufficient bandwidth to concurrently support live video and 3D graphics operations. The LVD exploits this by allowing an application to have full control over the superworkstation's graphics processing power. Priority can be assigned to either video or graphics — or it can be divided evenly.

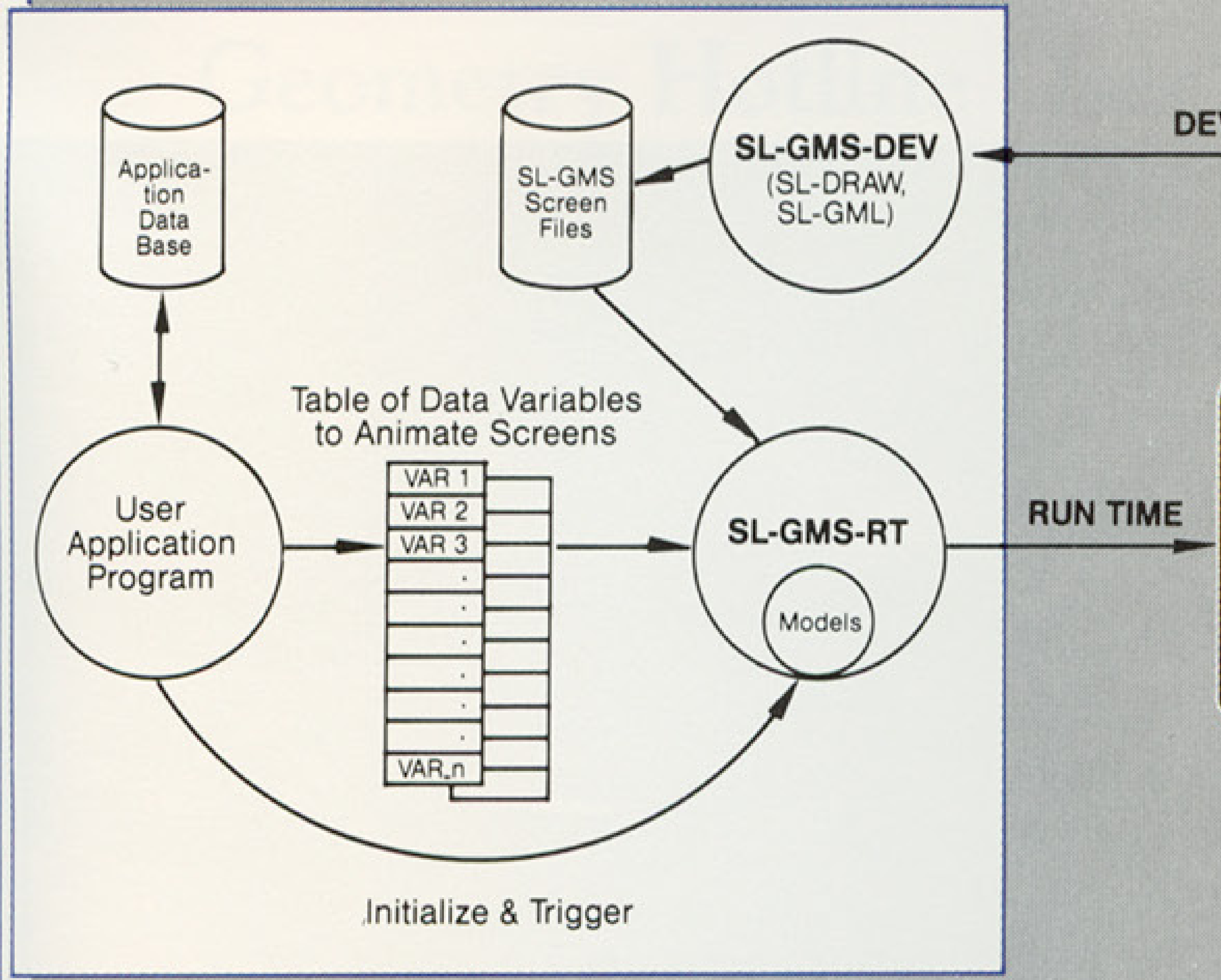
The live video option can be programmed for various video input rates, ranging from single-frame grab to live video speed. Two LVD versions currently are available: one supporting up to 30 frames per second and the other providing for up to 15 frames per second.

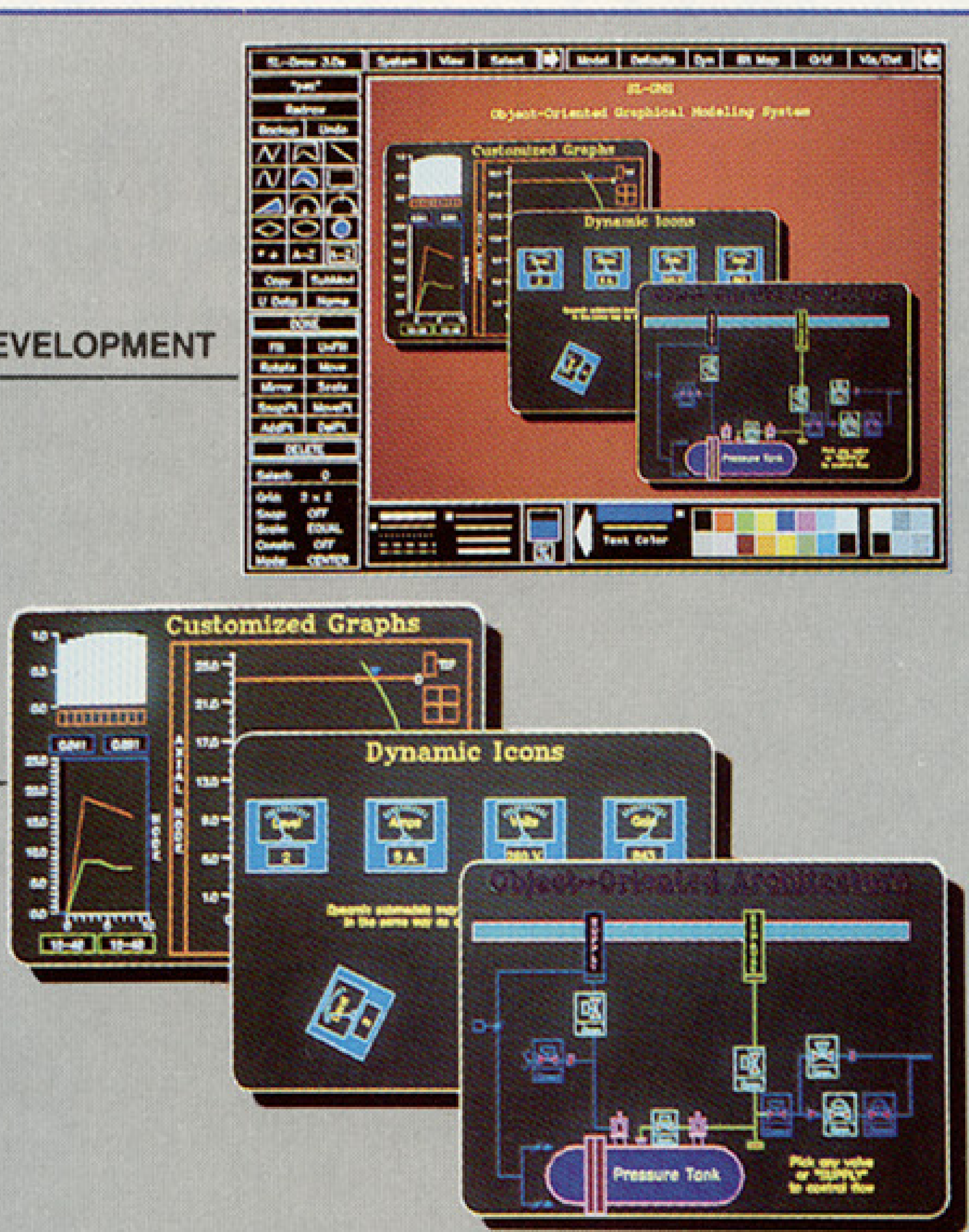
Pricing for LVD starts at $6000, with units available in September. For more information, call product manager Doug Campbell, at 415/335-1202. ■

SL-GMS (3.0e) . . . a complete system to build and animate precision, graphics screens.

Now, for Silicon Graphics users . . .
SL-GMS has been optimized to take full advantage of Silicon Graphics display-pipeline hardware.
Without writing any code you can create and drive complex dynamic graphics displays at real-time speeds, up to 20 Hz . . . as if you had written your own, direct IRIS-GL code.

. . . eliminates costly programming of dynamic, visual interfaces.
. . . codeless, optimized linking to real-time applications.





- **process control and display**
- **network monitoring**
- **custom, on-line graphing**
- **cockpit simulation**
- **data-base and expert systems integration**
- **data analysis and trader workstations**

Completeness of SL-GMS Development Tools lets you build the dynamic graphics screens you need quickly and easily and lets you specify exactly the screen behavior you want—without restriction.

The screen development process creates a collection of screen-description files using these tools:

The SL-DRAW Graphics Editor provides all features and menu-driven functions you expect from superior editors, and more: nested hierarchical symbols, single point-editing, object alignment functions, limitless color palette options.

This highly configurable editor can be used to rearrange its own menus or to extend or limit available graphics options.

In addition, SL-DRAW allows non-programmers to incorporate complex dynamic specifications into screen and icon descriptions. All attributes, like color, line style, fill percent, text string, position, or rotation may be connected to application data variables— either directly or through intervening formulas and conditional expressions.

A versatile previewing utility which can be invoked from the SL-DRAW program tests screens under development. Data can come from several specified sources—user data files and live data streams, or it can generate random, stepped, or sinusoidal data for simulation testing.

The SL-GML graphics command language interpreter provides an alternative method for accessing SL-GMS graphics functions. It also provides functions to convert ASCII/binary/C screen-file formats or define complex screens with multiple, tiled, or overlapping views.

The SL-GMS Run-Time Function Library is embedded in the application and manages all dynamic graphics tasks with little or no programming.

Screen description files created using the SL-GMS development tools are loaded into application programs and driven using the SL-GMS Run-Time Function Library.

Superior architecture makes it possible to control animation and dynamics through a simple table-driven approach linking data variables to screen elements, sub-elements, and/or text.

This provides users with a highly efficient graphics management sub-system—optimized for speed and performance at the lowest level.

No further programming is needed since native hardware performance has already been exploited by SL-GMS.

Advanced portability protects your investment in developed screens from every level of technical change.

SL-GMS is independent of particular graphics devices, hardware platforms, windowing standards and operating systems.

SL-GMS runs under VMS and most variants of UNIX. It has been ported to numerous native, real-time operating systems.

Full application-program interfaces are provided for C, Fortran, Pascal, and Ada.

A device-independent workstation layer simplifies and ensures the continued portability of SL-GMS:

On DEC equipment, both DEC-Windows and DEC-GKS are supported. On SUN workstations: SunView/SunWindow/News/X11. On Silicon Graphics stations: IRIS-GL (X11 when available). On a variety of other platforms: SL supports the vendor solution, usually X11, in some cases accompanied by PHIGS++.

Screens and programs built with SL-GMS on any supported platform can be transported effortlessly to any other supported platform. Build screens on lower-priced lower-performance hardware, and then run them on faster, more capable hardware . . .

Beyond widgets: complex multi-attribute icons can be created with no extra burden on programmers.

SL-GMS can support standard user-interface objects, referred to as "widgets", such as pop-up menus, scroll-bars, text-field entry.

SL-GMS goes significantly beyond widgets in supporting real-time graphics applications in unique ways.

SL-GMS provides a window-system-independent way to invoke an application function whenever a graphic "button" or "menu" is selected. Any graphic object may have such a "callback" function associated with it.

Additionally, SL-GMS generalizes X-widget behavior so that "radio buttons", for example, becomes radio behavior that can be applied to any group of objects. This approach is independent of, yet consistent with the many different approaches. Until "standard" window systems settle and a standard "widget" set emerges, the alternative provided by SL-GMS is powerful and 100% portable to any final standard.

More important, graphic icons or symbols created with SL-GMS can contain not just graphics, but also complex dynamic descriptions for each individual element.

Users can easily create a complex-dynamic symbol, such as a meter that contains multiple text readouts or changes color when a certain value is reached. Each occurrence of such an icon can be driven separately by individual data records in the application.

Real applications require much more than just simple menus and scroll bars—and SL-GMS provides the necessary capabilities.

Extensive Codeless Custom Graphing

SL-GMS provides a rich set of graphing primitives to permit the construction of both simple and complicated graphs.

Many basic graph types are provided. Users can readily produce XY graphs, scatterplots, trend graphs with linear/log axes, and barcharts, for instance. Data can come from files or from streams updating in real-time.

Some users can get by with a canned library of hard-wired graph types, but in most applications, customization to some degree is required.

With SL-GMS, the library of standard graph types that is provided can readily be extended and customized. Multiple axes/traces can be added to any graph, auto-scaling and multi-colored traces can be defined, custom legends and logos added for your own look and feel . . . all without programming.

License Prices

Development Configuration	
SL-GMS	12,500
Run-Time Module	
SL-GMS	3,600
Source code	
Available under Agreement.	

Call or write today.

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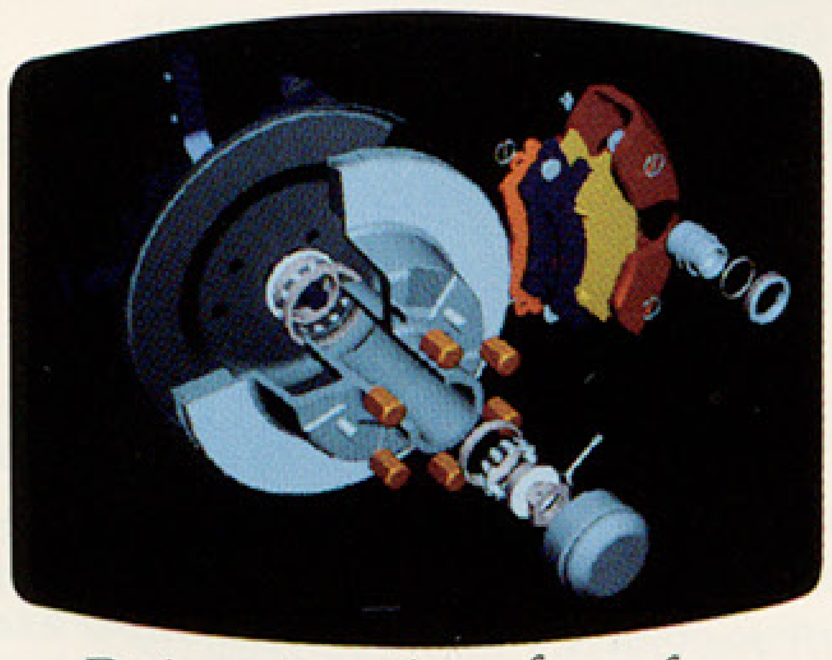
Not now. Not when you have already spent thousands of man-hours and your entire budget getting a product into production.



Design automation software from SDRC helps you deliver superior products on time and on budget.

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SDRC

CUSTOMER EDUCATION

Geometry Hotline User's Guide Now Available

By Tom Loupy

The Silicon Graphics *Geometry Hotline User's Guide* is now available, free for the asking. Produced to explain the many attributes of the Geometry Hotline, the 12-page reference guide touches on:

- What services the hotline provides.
- How and when to use the hotline.
- What to do before placing a call.
- What response to expect.
- What's done to close a call.

Silicon Graphics has a variety of support services available to the end user, including hardware maintenance, software support, and customer training. The Geometry Hotline is the gateway to most of these. Whether your intent is to request that a Silicon Graphics Field Engineer be dispatched for onsite service, to order a replacement part, to schedule service for an old part, or to request over-the-phone technical assistance, the Geometry Hotline is the place to call.

Intended to help customers take full advantage of these services, the guide indicates who and when to call. Pointers to alternative resources also are provided.

To get a free user's guide, call the SGI Customer Information Center (800/338-6272). ■

Tom Loupy is an SGI Customer Education product manager.

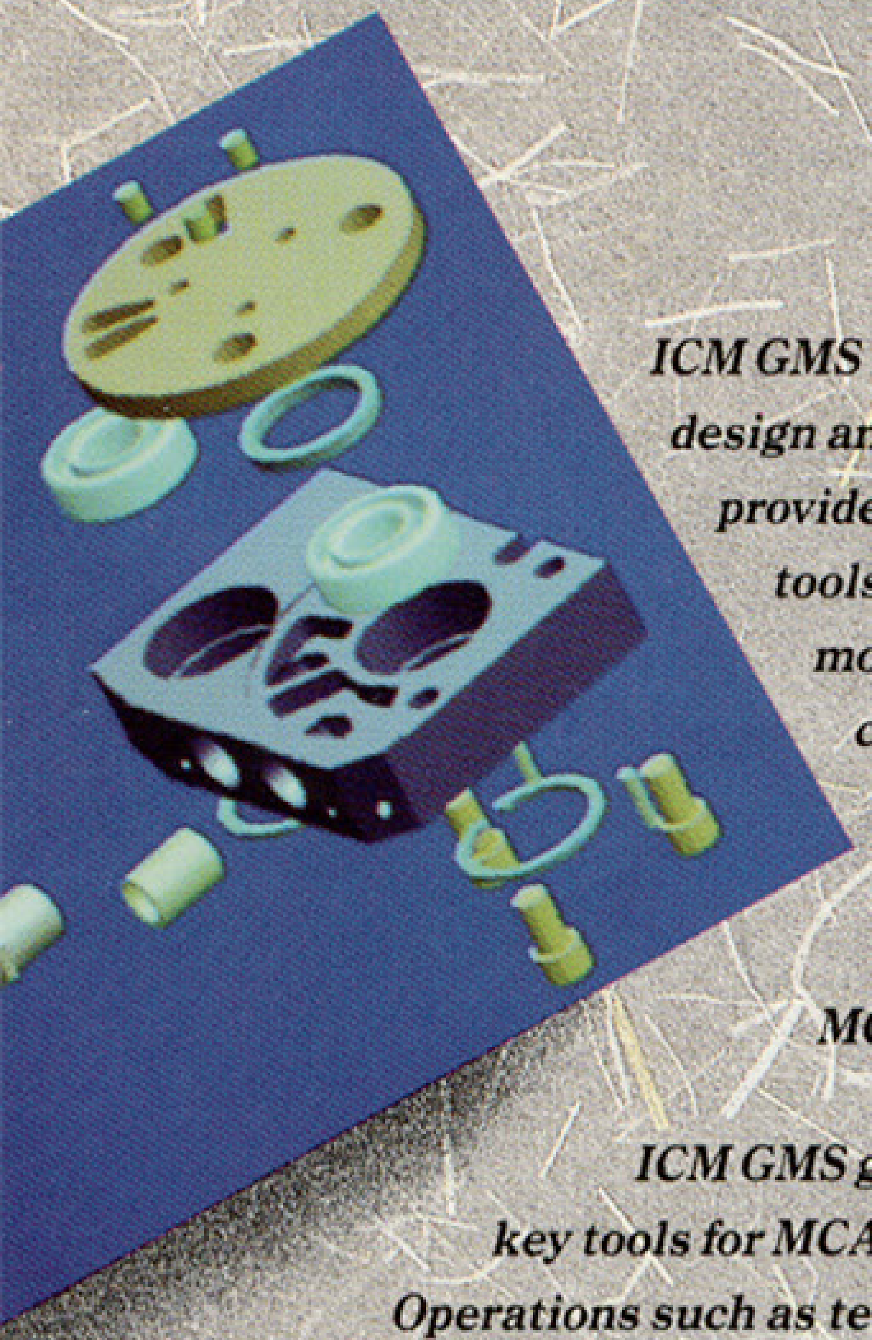
SILICON GRAPHICS, INC.
EDUCATION CENTER
COURSE CALENDAR
(Through December 1989)

COURSE	*LOCATION**	
4D SERIES COURSES	**WEC**	**EEC**
Graphics I *4.5 days*	Aug 14, 1989 Sep 18, 1989 Nov 13, 1989	Aug 7, 1989 Oct 23, 1989 Nov 27, 1989
Advanced Graphics *3.5 days*	Sep 25, 1989	Aug 14, 1989 Dec 4, 1989
Parallel Programming *4.0 days*	Aug 7, 1989 Sep 11, 1989 Nov 6, 1989	not available
System Accelerator *4.5 days*	Nov 27, 1989	Sep 11, 1989 Oct 2, 1989
System Administration *4.5 days*	Dec 4, 1989	Sep 18, 1989
Network Administration *4.5 days*	Dec 11, 1989	Sep 25, 1989
System Maintenance *10.0 days*	not available	Oct 9, 1989
Personal IRIS Maintenance *3.5 days*	Oct 9, 1989	not available
Multiprocessor Maintenance *4.0 days*	Nov 13, 1989	not available

KEY: WEC—Western Education Center, Mountain View, CA.
EEC—Eastern Education Center, SGI Federal, Bethesda, MD.

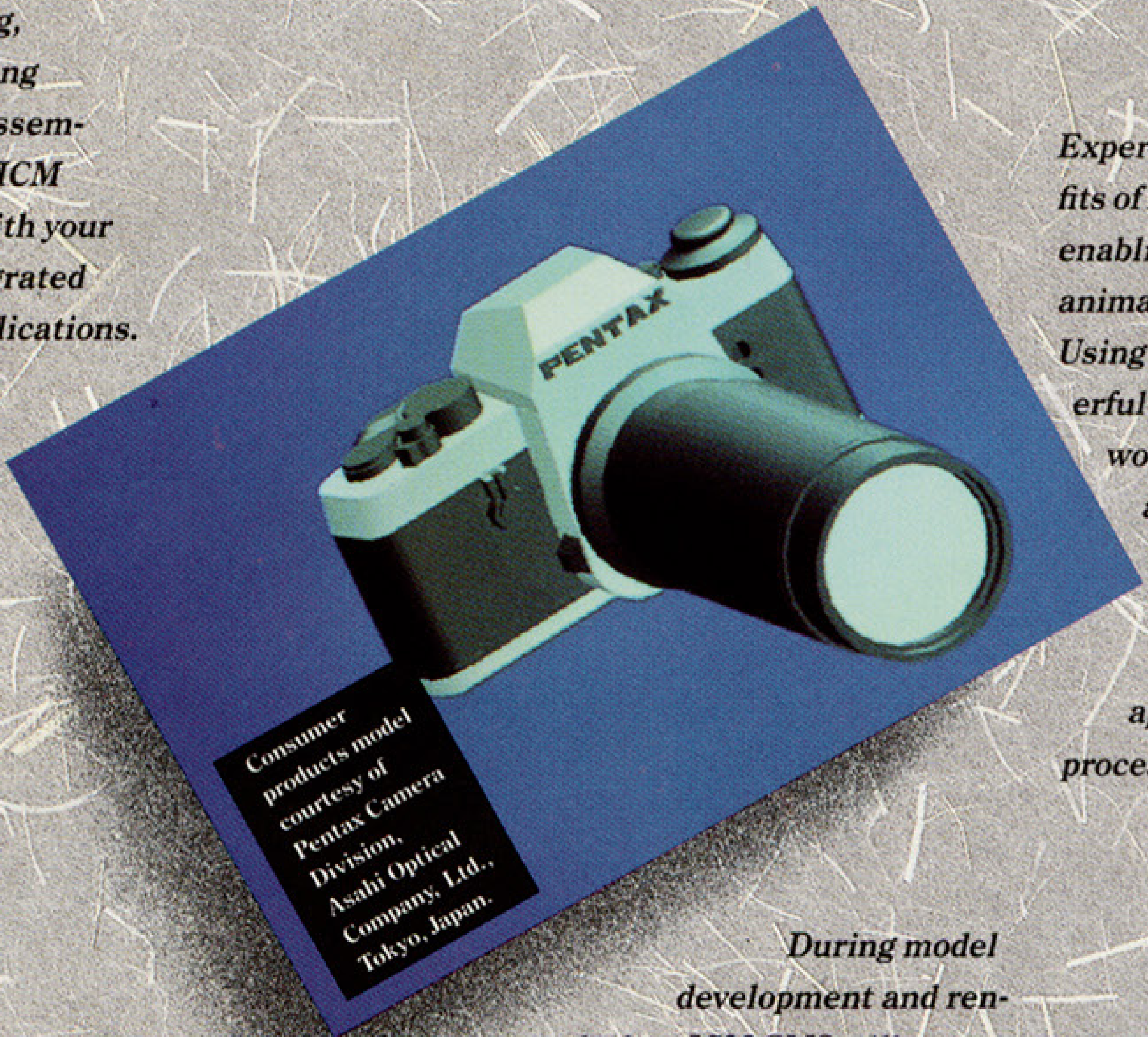
* The SGI Education Center reserves the right to cancel classes due to insufficient enrollment.

The Best MCAE Solution Is On Trial



ICM GMS is the heart of your design and analysis system. It provides highly interactive tools for conceptualizing, modelling and analyzing complex parts and assemblies. You can use ICM GMS alone, or with your choice of our integrated MCAE/CAD/CAM applications.

ICM GMS gives you key tools for MCAE analysis. Operations such as testing for interferences and calculation of physical properties are direct and rapid.

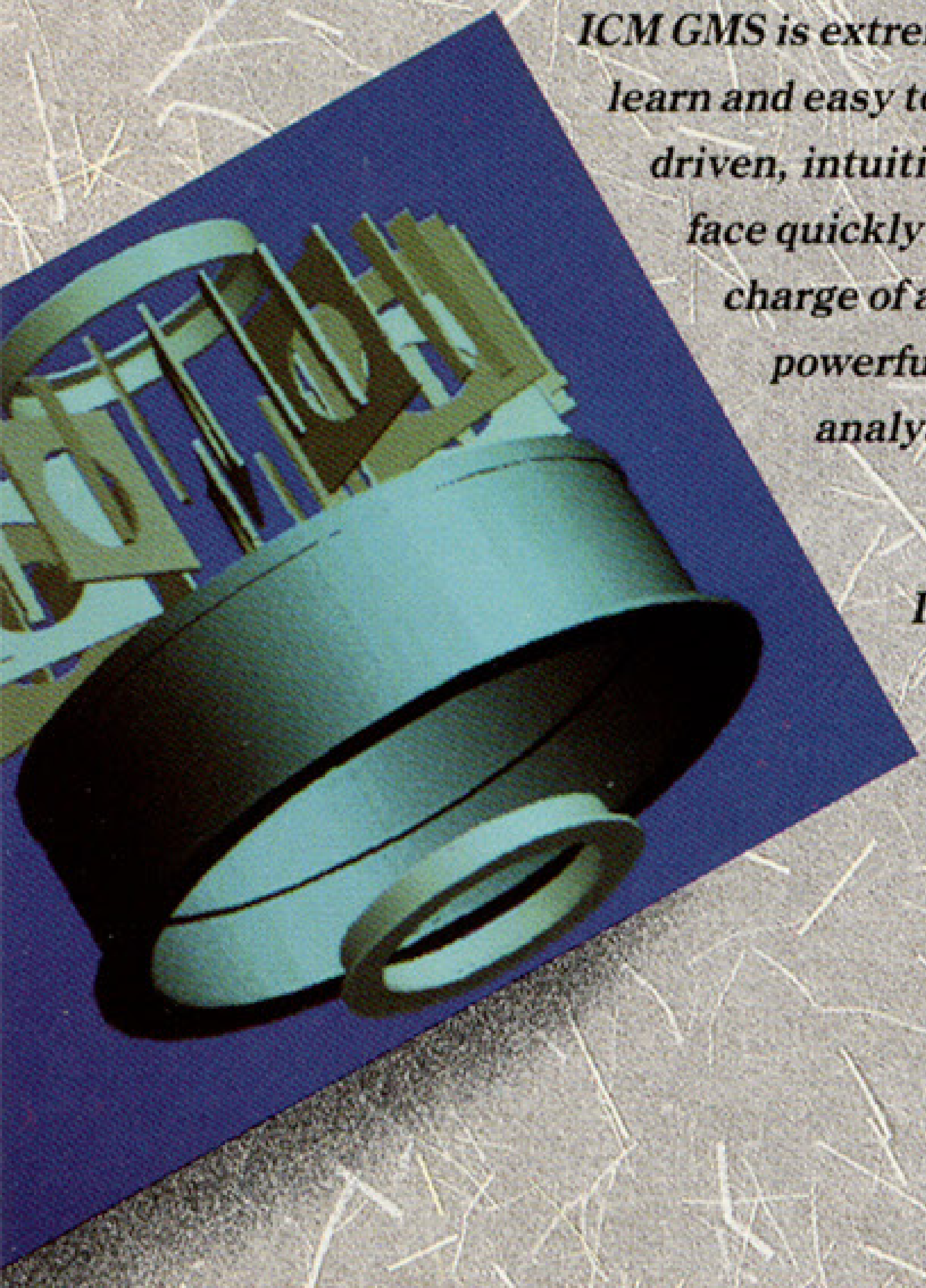


Consumer products model courtesy of Pentax Camera Division, Asahi Optical Company, Ltd., Tokyo, Japan.

Experience for yourself the benefits of fast ICM GMS graphics, enabling you to color-shade and animate 3D models in real time. Using the full resources of powerful Silicon Graphics IRIS workstations, ICM GMS will accelerate your complex model development. And greatly enhance your visualization of MCAE application pre- and post-processing results.

During model development and rendering, ICM GMS will automatically generate macro files for parametric design and family of parts generation. You'll experience measurable reduction in design cycles.

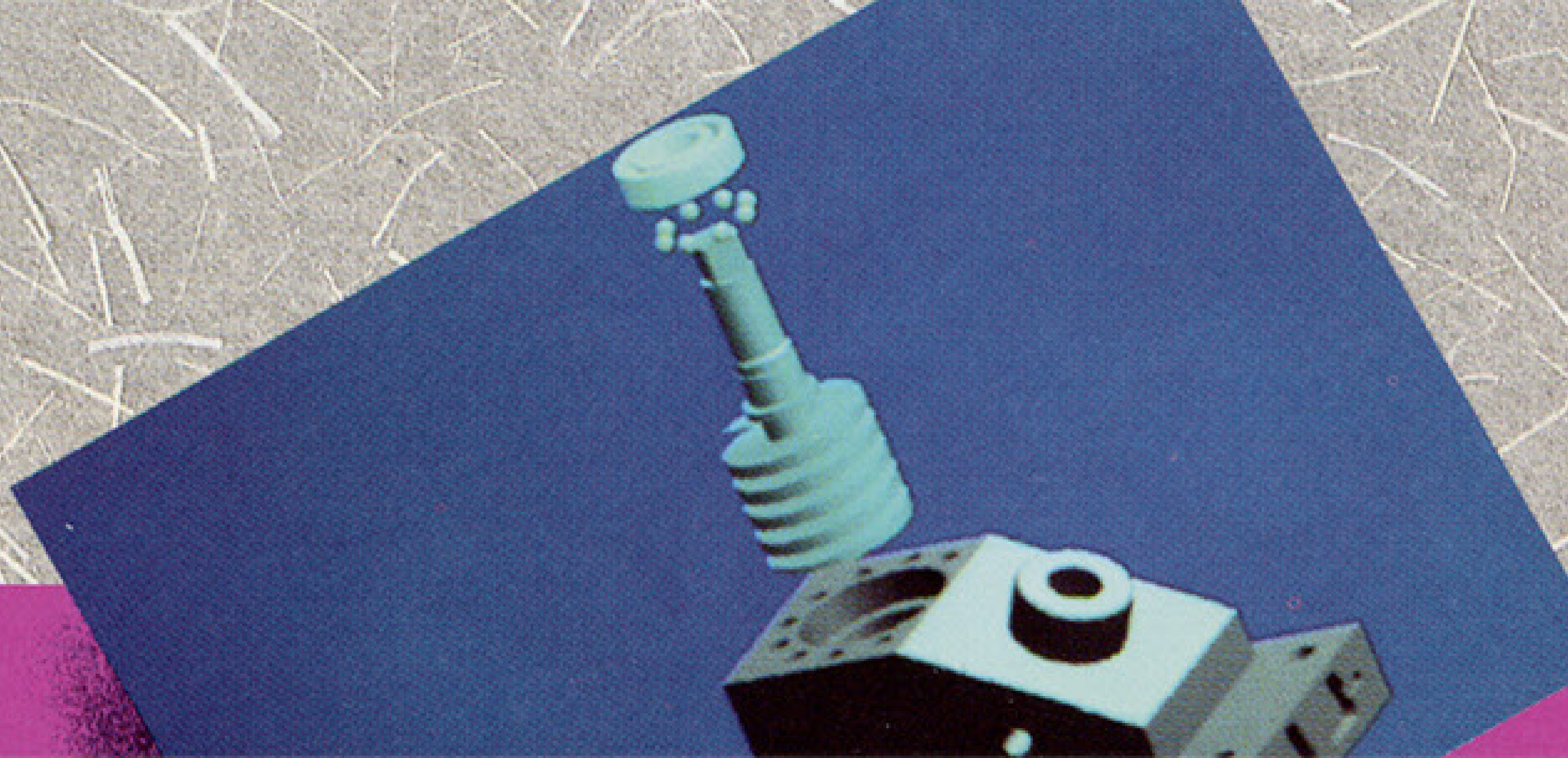
Factory automation model courtesy of Automated Manufacturing Research Facility, National Institute of Standards and Technology (formerly National Bureau of Standards), Gaithersburg, MD.



ICM GMS is extremely easy to learn and easy to use. Its mouse-driven, intuitive human interface quickly puts the user in charge of a full range of powerful design and analysis tools.

ICM GMS performs with exceptional accuracy, efficiency and reliability on CAM-I standard benchmarks.

ICM GMS is integrated with state-of-the-art applications from strategic software partners in every key MCAE area—CAD, CAM, FEM/FEA and kinematic and dynamic analysis. You get all the state-of-the-art advantages of specialized applications from leading independent developers—and the best complete MCAE solution—only from ICM.



And No One's Being Charged!

Kinematic and dynamic analysis model courtesy of Automation and Robotics Laboratory, U.S. Army, ARDEC, Picatinny Arsenal, N.J.

There's no good reason to buy any MCAE software without a trial. Now you can try out the best MCAE/CAD/CAM solution in your own facilities. At no charge.

See what ICM® and its strategic software partners—today's most powerful and comprehensive MCAE solution—can do for you. We'll train you free at ICM offices in preparation. *Then you be the judge.*

Demand Proof

You will find that ICM is *THE LEADER* in solid modelling and visualization. You'll see first hand that ICM GMS® (ICM Geometrical Modelling System®) software provides uncompromising design and analysis tools. You'll see how ICM GMS uniquely exploits the real-time, 3D power of Silicon Graphics™ IRIS™ workstations. And you'll watch ICM GMS increase efficiency and productivity in your own facilities. Why should you commit to a system without this indisputable proof? *You shouldn't.*

Hear The Testimony.

The next acid test in evaluating an MCAE system is its references. *Real* references. Some companies will send you a pre-screened list of users they can count on. We'll send you a *100% list of all ICM GMS customers.* An international list that includes some of the highest-powered, most experienced MCAE users, OEM's, VAR's and system integrators today. Get the unvarnished testimony of real ICM GMS customers. Consider all the evidence. *Why make a decision with less?*

Put ICM GMS On Trial—Without Charge.

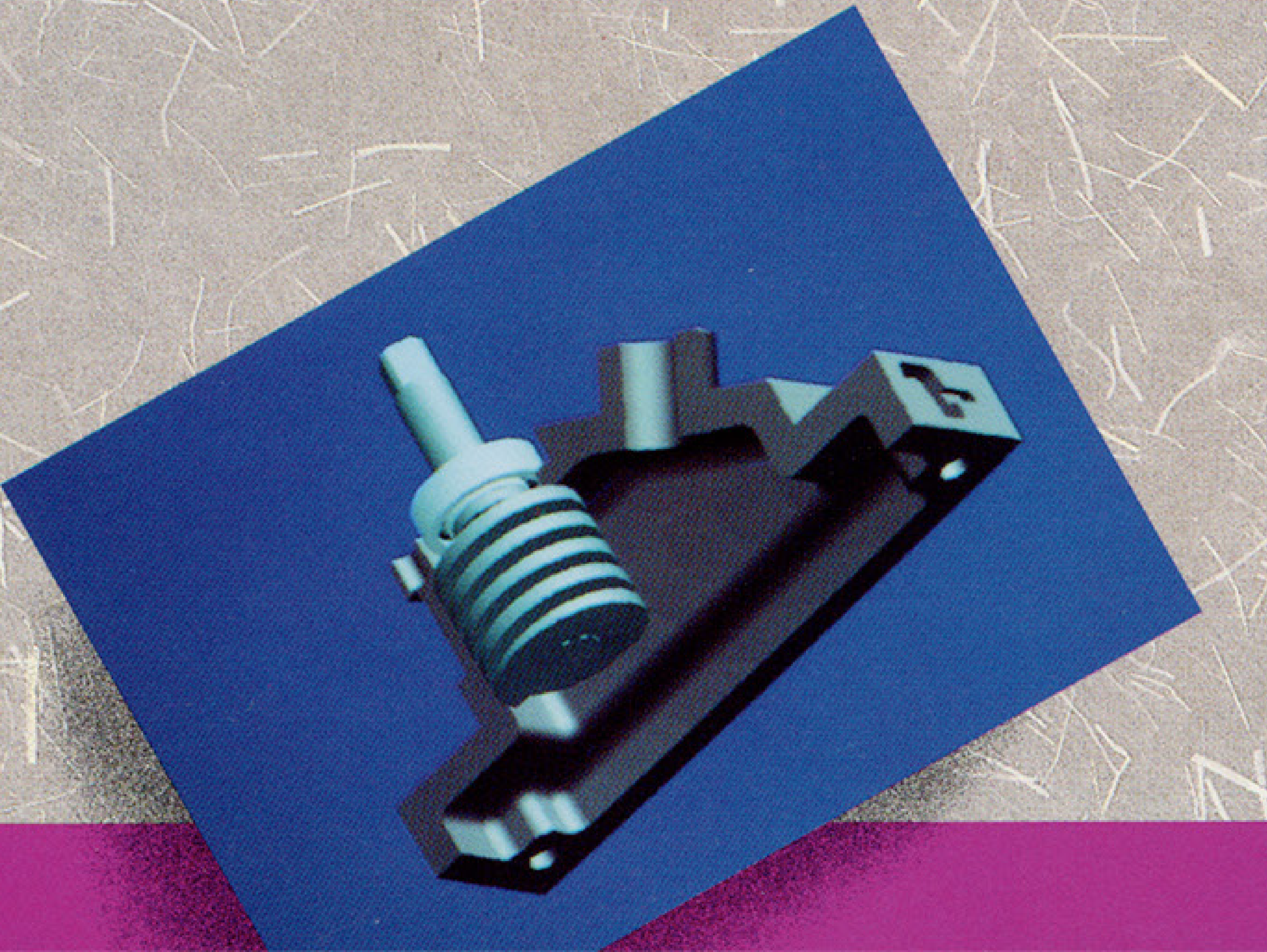
- **Arrange to try out ICM GMS.**

Don't buy any MCAE software without trial. Experience the advantages first hand. Then decide.

- **Get a 100% reference list of ICM GMS customers.**

Don't select a system without references—from all its users.

Call today! **703-476-1600**



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